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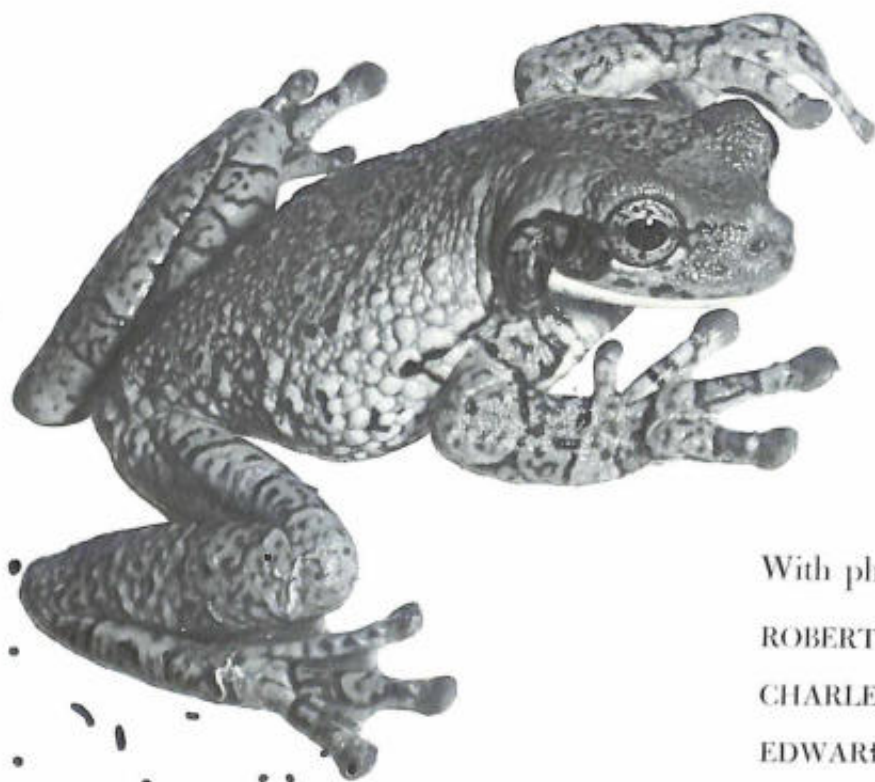
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*Living Amphibians of the World*



# *Living*



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# *Amphibians of the World*

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# Preface



**A**LTHOUGH the amphibians are not often noticed by most people, they nevertheless play so important a role in the world of living creatures that it was felt that they deserved a separate volume in this series of books on living animals. On the evolutionary scale they form the link between the fishes and all higher vertebrates, such as reptiles, birds and mammals, since they were the first group of vertebrate animals to emerge from an aquatic environment and live upon land for most of their adult lives. While many of their fossil ancestors may never be known, those that we have discovered were already extremely varied in structure and habits some 230 to 280 million years ago, when the first bones to be preserved in rock deposits were laid down. Their descendants in the living world of today number about 3000 species, some of which are found in almost every habitable region on our globe.

Most readers are doubtless not aware that the amphibians are the least harmful to man of any major zoological class. None of them has a poisonous bite, as do some of the snakes; they do not rob fields of grain and fruit, as do many birds; none of them is ferocious, like the carnivores, or destructive, like some rodents; they do not have such poisoned barbs as some fish possess, and they have inflicted no major diseases upon us, as have such invertebrates as insects or protozoans.

Indeed, the effect of the amphibians, when they come into contact with man and his projects, is often beneficent. Their appetites are all in our favor, for most of them prey on insects and their larvae, and thus act as a check upon our all-too-prolific competitors for the world's food. They also become food for man when they grow to sufficient size to make a mouthful. Their often elegant shapes and colors, well exemplified in the engravings in this book, have been copied on prized art objects ever since prehistoric times, since some of the living animals are a delight to the eye of the most discriminating observer. It is true that many amphibians secrete from their skin an acrid substance irritating to their predators, but that is not usually a hazard so far as man is concerned.

Many amphibians live far removed from man's orbit, but even these take on considerable scientific value when their habits can be studied and when they lend themselves to the experiments by which man seeks to know more about himself through the reactions of other animals under natural or artificial conditions.

In primitive man, knowledge of the living creatures about him is usually limited to those which are important to him by serving as food, or by endangering him. He knows little, and cares less, about non-aggressive or secretive animals such as caecilians, salamanders and frogs.

The early Greek philosophers often delighted in observing at first hand the native animals about which they wrote so fluently, but they also accepted as true the sailors' myths and misconceptions of animals in foreign lands, and retold these tales with

such assurance that they were given credence among scholars of their time and of the next two thousand years.

During the Middle Ages the mind of European man was submerged in superstition; it was not until the sixteenth century that a real attempt was made to describe the wonders of the living world. Then, between 1551 and 1587, the Swiss naturalist Conradus von Gesner published a five-volume set of books on animals, and Aldrovandus of Italy in 1640 brought out the first book that dealt entirely with amphibians and reptiles. These were illustrated by woodcuts that bore little resemblance to the actual creatures. In 1693 John Ray, the English botanist who had turned to the study of zoology, dissecting animals to show that internal characteristics were of the greatest value in grouping them correctly, published a book based on the anatomy as well as the external appearance of animals.

A flood of lengthy Latin treatises on zoology followed, and while most of these seem crude and even laughable today, they made a beginning of the serious study of animal variation. They were difficult to read, however, as most wild animals lacked definite and universally accepted names. It was the Swedish scientist, Carolus Linnaeus, who brought order out of this chaos by inventing a system of nomenclature in which every living thing—plant or animal—has two names: the genus, usually, a Greek word or derivative, that is applied also to the close but not identical relatives of the animal in question; and the species, usually a Latin derivative, that belongs solely to the particular animal. Work progressed rapidly in all literate countries during the eighteenth and nineteenth centuries, for the use of the Linnaean system encouraged coordinated thought and exchange of scientific knowledge by scientists everywhere.

Soon the study of zoology—and of herpetology, that is, the concern with reptiles and amphibians—grew far beyond its original bounds. Travelers and explorers, such as von Humboldt, Bates, Wallace and dozens of others, penetrated to the most remote lands armed with nets, jars and notebooks to capture “new” species and record their living habits and colors. A vast literature concerned with the naming and describing of animals, called taxonomy, sprang up, headed by such famous biologists as Tschudi, Fitzinger, Cuvier, Gray and others. The emphasis today is largely on experimental biology, but students in nearly every part of the world are devoting time to some phase of the study of amphibians. During 1955, for instance, over five hundred individuals published from one to six scientific papers in standard journals, and their number is ever increasing.

*Living Amphibians of the World*







# Introduction

MANY millions of years ago a curious fishlike creature crawled out upon the shore of a steaming jungle lake into a world so utterly different from ours of today that we can scarcely conceive it, even with the help of fossil reconstruction. A few small primitive plants had come into being, but no birds flitted above them and no mammals prowled in their shade. Birds and mammals were still a long way in the future, as were dinosaurs and other reptiles.

The fishlike creature breathed air with difficulty, but it *did* breathe air, and so it became the first wayfarer on the long and rugged journey from its earliest home in lakes and marshes to final dominion of the land. Ages later its descendants breathed air more readily, and they could travel farther from the water in which they still passed their infancy. As there were no predatory enemies to persecute them, they thrived apace and flourished in their new home on land.

After many trials brought on by the drying of the land and the shrinking of the waters, a class of animals now called the Amphibia came into being. They were bound to the water by their need for keeping their eggs moist and for the nurture of their larval stage, but once adulthood was reached, most of them hopped or crawled away from the lake that had been their earliest home, and eventually came to dwell on land, lurking under stones or burrowing in earth in search of moisture to dampen their spongy skins.

The word "Amphibia" means literally "double life," and refers to the ability of these animals to live in water or on land at different times. In the aquatic phase, gills like those of fish help them to absorb oxygen from water. While some amphibians retain their gills throughout life and never leave the water permanently, in most of them the gills are gradually absorbed as the larva grows. At the same time lungs begin to function, and by the time metamorphosis is complete, we have an air-breathing land dweller, which can creep, climb, hop, or burrow.

The living amphibians that exist today are divided into three orders: the Gymnophiona (caecilians—legless, burrowing amphibians that live only in the

tropics and are not often seen because of their secretive habits); the Caudata (salamanders); and the Salientia (frogs, toads, and their close relatives). Other orders are known only from fossil remains. In general, I have used the word "frog" to cover all tailless amphibians. Wherever a species has a popular name I have used it.

The earliest skeletons definitely known to be amphibian date from the Devonian period (about 280 million years ago), and fossil footprints of supposedly amphibian origin are known from the earlier Devonian period. The ancestors that gave rise to those traces must have been developing for aeons before that time. Amphibians were the dominant type of tetrapods in the Carboniferous period, and multitudes of kinds must have lived, died, and disappeared without leaving a single bone. The few we have from the fossil beds differ greatly in size, some being only an inch long, others attaining a length of eight feet, far larger than any of their descendants living today.

Paleontologists have been able to tell in some measure what the ancestral amphibians looked like. Some were slender and snakelike in appearance, while others had four legs and a tail, and scaly armor on the body somewhat like that of the lizards. Still others retained their gills throughout life and doubtless were smooth-skinned, perhaps slimy like modern salamanders. In a few instances the rock in which amphibian remains are found has kept traces of the soft internal organs, so that we have a good idea of the structure of the alimentary canal in at least one fossil form, *Eumicreron*, from the Mazon Creek locality in Illinois.

Some of the fossils unearthed before comparative anatomy became an exact science were not recognized as amphibian. A large fossil salamander was described in 1725 as the skeleton of "the man that witnessed the Deluge," and an engraving of it was reproduced in the "Copper Bible" as an undeniable proof of the accuracy of the biblical story of the Flood.



Fossil amphibians are found occasionally in beds of coal shale, pressed flat by the weight of rock that formed above them, but often with the smallest details of their body structure preserved in the stone. Some amphibians of the Pennsylvanian period were salamander-like in form, and near the close of the period appeared small, slender-legged, aquatic forms which are assumed to be the distant ancestors of our present-day salamanders, the second order of the Amphibia. The first order, the caecilians, has not yet been discovered among the fossils.

The third order of living Amphibia is the Salientia, the group comprising frogs and toads and their relatives. It is known from a few fossils in the Jurassic epoch. These were already built for jumping and leaping, so we must assume that this specialized type of leg structure began to develop long before Jurassic times.

Although climatic and geologic changes have been the rule since those early days, frogs have always shown the widest adaptation to nearly all kinds of living conditions. They are found today on every continent except Antarctica, and usually in abundance. The greatest variety occurs in the tropical jungles of the Old and New Worlds. There some frogs have become exclusively tree dwellers, never descending to the ground. Their eggs are laid in rain water caught in cuplike leaves of certain air plants called bromeliads, which cling to the topmost tree branches. "Rock-a-bye, baby, in the tree top" is literally true for their tadpoles, for their aerial cradle is rocked by the wind and drenched by storms. Unless the tree beneath them crashes in a tempest, they survive very well in their elevated nursery, for there are no predatory fish to swallow them, as is often the case with tadpoles living in natural ponds on the ground. Instead, they live in a company of bromeliad dwellers, such as tree snails and worms, as well as flying cockroaches and other insects of many descriptions. Their transformation from egg to tadpole to adult is usually rapid, for even in the jungle a dry season comes, and then there are no more daily rains to fill their leafy bathtubs to the brim.

At the foot of these same jungle trees is a completely different world—one of hopping and burrowing amphibians. Chief among these are the toads (genus *Bufo*), known from all the continents except Australia and Antarctica, and comprising about two hundred different species. These fat fellows, not built to be speedy or agile in securing food or avoiding danger, are protected by a slimy exudation of the skin, centered in the bulging parotoid glands behind the eyes. This substance is a highly complex protein

compound, bitter and smarting when brought in contact with a mucous membrane, so that a wolf or fox that has once picked up a toad in its mouth will never care to do so again. Being thus protected from his larger enemies, the toad calmly hops on his way, picking up beetles and other creeping insects with his sticky tongue, and pausing to rest under a slab of rock or in some crevice during the daylight hours.

Other froglike or toadlike amphibians roam the forest floors. One genus called *Eleutherodactylus* (one of many that have no common English name), found in the New World tropics, develops without the free-swimming tadpole stage. Its eggs, large and relatively few in number, are laid in cavities of trees, or sometimes in the sides of banks. The egg hatches as a minute but fully-formed froglet, with no trace of gills or tail, these having been developed and absorbed during the egg stage.

Desert dwellers are no less interesting than those of the jungle, and since their very existence depends upon the small amount of water they can find, they are invariably clustered about an oasis or a well where they can get a share of this vital element. In the Southwest of the United States, the Colorado River toad, *Bufo alvarius*, is attracted to cattle troughs, and its numbers may actually be on the increase since man began to make these reservoirs.

The canyon tree frog, *Hyla arenicolor*, also from the American Southwest, lives happily in tree-lined canyons, and, strange to say, is quite aquatic, never wandering far from small streams or mountain springs.

In the true waterless deserts, such as Death Valley in the United States and parts of the Sahara, no amphibian life is possible. But sometimes frogs can find moisture by burrowing when the surface of the ground is dry. A whole "anthill" fauna exists in semi-arid regions in Africa and Australia where the giant termite nests occur. In the galleries built by the busy insects, little globular frogs spend a secluded but extremely well-fed life, preying upon the hurrying termites as they rush past on some important anthill business.

Among the places in which frogs and toads are never found are the sea and regions of constant cold. A small amount of salt water is fatal to most developing tadpoles, and even an adult frog will die in a few moments if immersed in sea water. There are a few exceptions, however. In the Argentine a toad, *Bufo arenarum*, breeds and deposits its eggs near the sea-coast in pools of water that is made semibrackish by spray from the Atlantic; so here is one species at least that has built up some resistance to salt water. One



toad, *Bufo halophilus*, from western Nevada, California, and northern Lower California, is sometimes called the "salt-marsh frog," and more often the "alkali toad," from its assumed ability to live and breed in alkali-impregnated marshes.

As to endurance of cold: while amphibians hibernate during the winter, thus managing to do without food because of a vastly lowered metabolism, there must be a yearly season of warm weather, with a minimum duration of some weeks, in which they will have time to mate, lay eggs, feed, and prepare for another long dormant period. The tadpoles must accelerate their development and begin life as frogs while the short summer lasts, for they do not have much time to eat and grow before the long winter arrives to stop their activities. Thus we find the northern toad, *Bufo boreas*, in southern Alaska, and the mink frog, *Rana cantabrigensis*, up to the mouth of the Yukon in Alaska and to the Mackenzie delta in Canada; but there are none in the permanently frozen ice fields of the northern rim of the North American continent. In Sweden, a frog, *Rana temporaria*, occurs to well within the Arctic Circle.

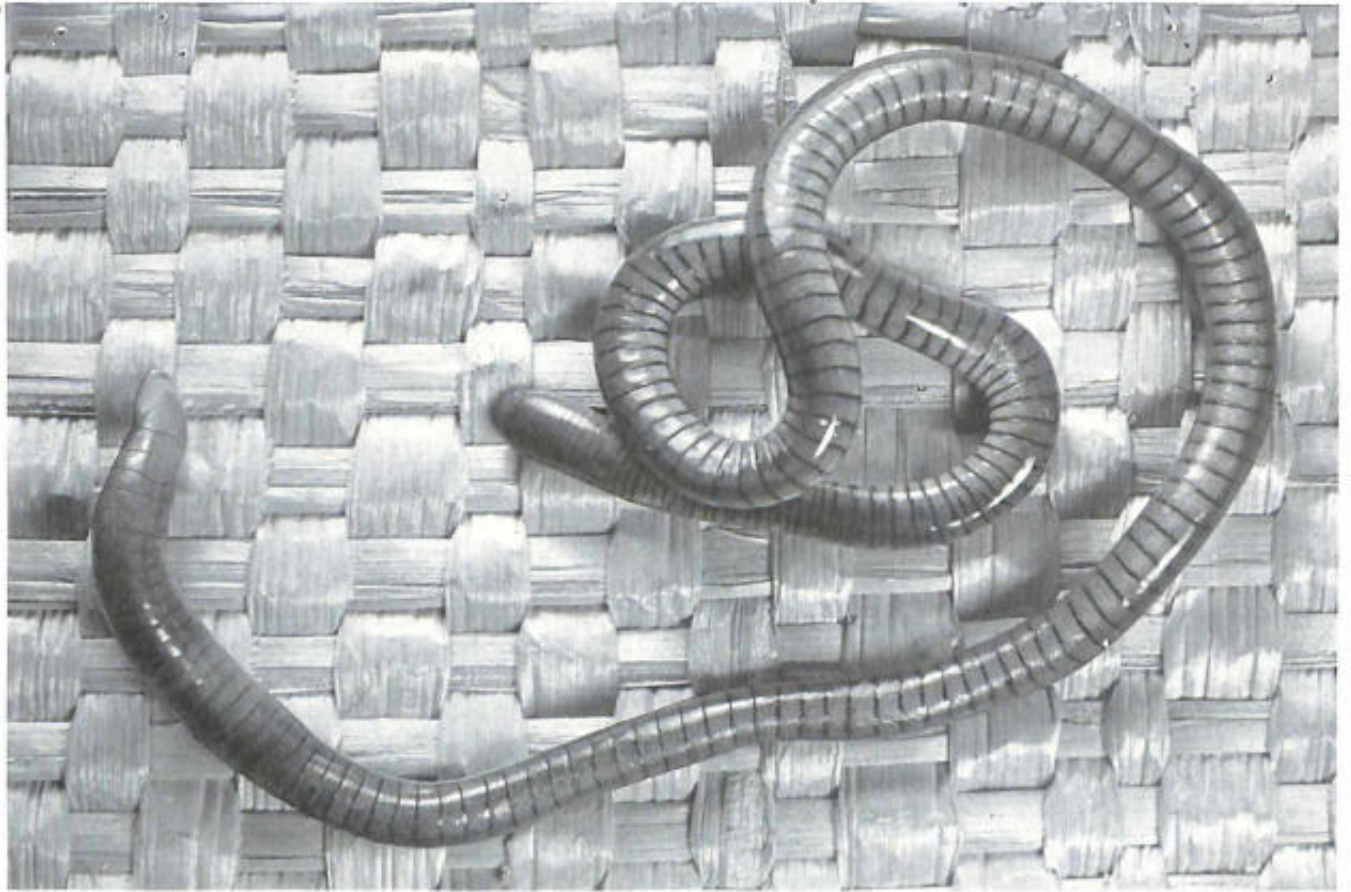
As to vertical distribution, frogs are found high up in the Andes and Himalayas, almost as high as the beginning of the permanent snowcap, or about fifteen thousand feet. Underground, their small, soft bodies could not withstand the weight of earth that a deep burrow would entail; therefore we do not find them

in burrows of their own making more than a few feet below the surface. In natural caves and in deserted mines, they of course can go much farther. Some stray too far inside and never find their way back to the entrance, as excavations in cave floors have proved. But the entrance to a cave or mine, with its cool shade, its dripping walls, and the abundance of insects that also seek its protection, makes an excellent foraging ground for a frog or toad.

The newspapers often print accounts of the opening of cornerstones of buildings being torn down after many years of use, and the finding of a live toad, presumed to have been buried in the stone at the erection of the building. Experiments have proved that toads cannot live much over a year without food, even when an abundance of water is provided. The live toad in the cornerstone must therefore have entered, not long before its discovery, through a crevice or hole in the foundation.

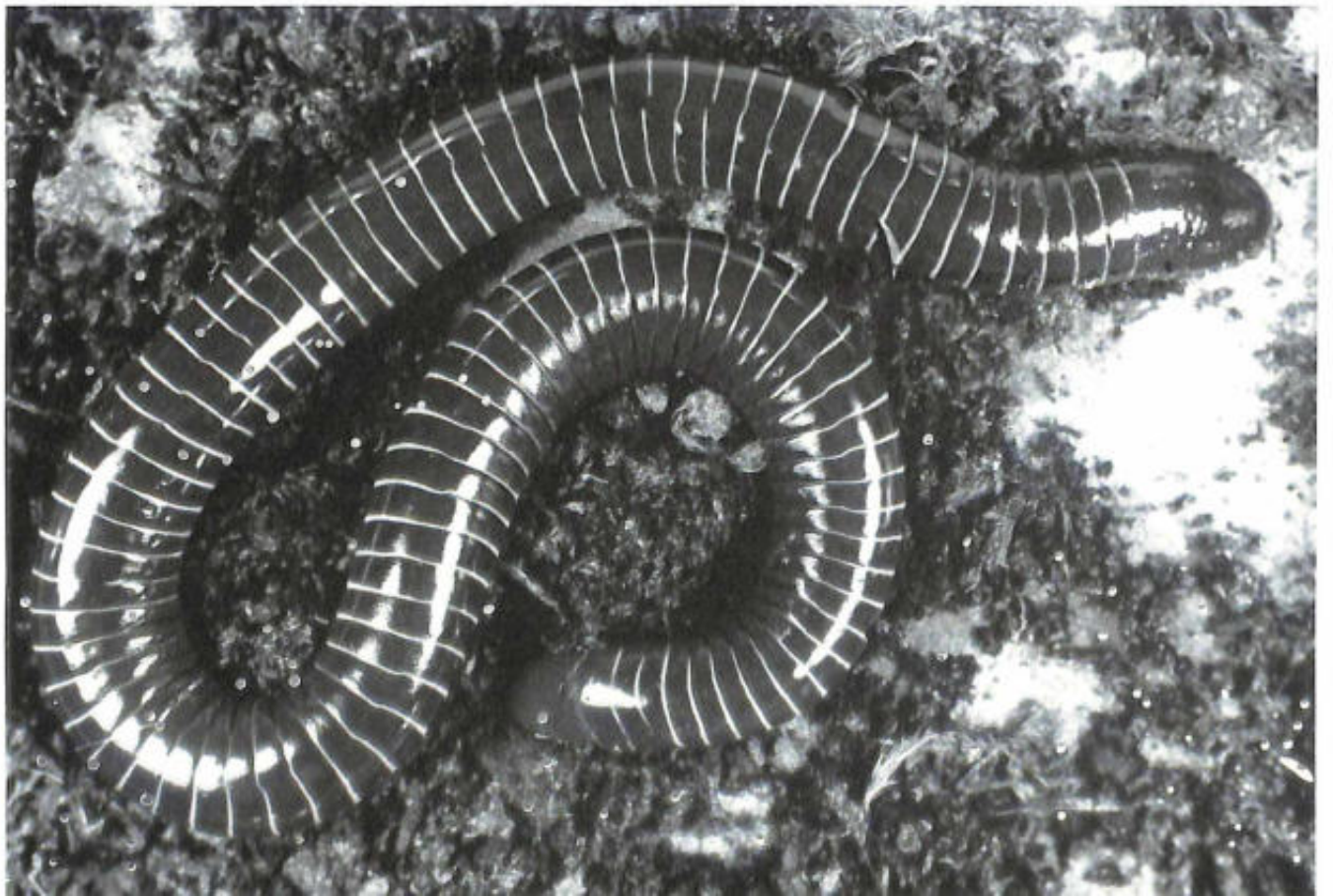
A perfectly natural thing for a toad to do when seeking to escape dry or hot weather is to hide in the cool, clammy comfort of a stone or brick retreat. This explains the scarcity of amphibian life during a drought of long duration. While some undoubtedly stay at the pond site and are killed by the heat, most frogs and toads leave a drying pond and go under debris, into rock crevices, even into hollow logs, to wait for the next rain in what little moisture there may be in such places.





Panamanian caecilian (*Caecilia ochrocephala*). Lorus and Margery Milne

South American caecilian (*Siphonops annulatus*). Carl Gans





# The Caecilians

(Order *Gymnophiona*)

**H**UMAN beings can sympathize with and understand those animals that seek the light and move over the surface of the earth in an eternal cycle of getting food, reproducing themselves, and then dying. But our minds can scarcely reach out to those that dwell underground and follow a completely different mode of existence. Thus it is impossible for us to fathom the "feelings" or nervous reactions of such subterranean creatures as the caecilians (pronounced "see-sil-ians"), the first group of living amphibians.

They live in underground burrows in tropical and warm temperate regions—in the New World from Veracruz and Guerrero, Mexico, south to Guayaquil, Ecuador, in western South America and to Buenos Aires, Argentina in the east; and in the Old World in southern Asia, the Malay Archipelago, the Philippines, the Seychelles, and parts of Africa. In altitude they range from sea level to over six thousand feet.

A single family, the Caeciliidae, contains all the known forms—sixteen genera and seventy-five species. Forty-six species are recorded from Central and South America, six from Asia, and twenty-three from Africa and the Seychelles Islands.

Most caecilians burrow in soft earth, and very seldom come above ground except when a heavy down-pour of rain happens to fill their burrows and wash them out. At least one genus, *Typhlonectes*, is aquatic, while the larvae of several other genera are aquatic in their early stages.

They are limbless, and do not even retain internal traces of a pelvic girdle, a lack that is an indication of their extremely primitive structure. Only one other amphibian group, the Sirenidae of the salamanders, lacks a pelvic girdle.

The eyes of caecilians are small and often useless in the adult stage, since they may be covered either by skin or by the maxillary bone. To take the place of eyes, which are unnecessary in a wholly subterranean

life, a peculiar sense organ in the form of a tentacle lies in a groove of the maxilla between the eye and the nose. It may be protruded when the animal is creeping about in its burrow.

Their skin is not like that of other amphibians. It feels slimy and smooth in adults, but when it is dissected, small scales are found imbedded in the skin below the slime glands in most species. No such scales exist, however, in the Indian genus *Gegenophis* or in the American *Siphonops*, *Typhlonectes*, or *Chthonherpeton*.

Some caecilians, due to their extreme elongation, may have over 200 costal grooves. The left lung is reduced, as in snakes, and the right one is very long. To the casual observer, caecilians look like oversized earthworms. A few grow to a considerable size, the largest known species, *Caecilia thompsoni* from Colombia, being about 4½ feet in length, while two other species of that genus are known to exceed a yard. The smallest ones are probably *Siphonops hardyi* of Brazil and *Gymnopsis parviceps* of Panama, both of which attain a length of only 7 inches. None of the Old World caecilians seems to exceed 20 inches. Stout species may be slimmer when young, and slender ones may be fatter in their early days, while some retain the same bodily proportions throughout their lives. The greatest body diameter is slightly over an inch, and this has been recorded for but three species—*Gymnopsis mexicana* from Mexico to Nicaragua, *Caecilia tentaculata* from Darien to Brazil and Peru, and *Typhlonectes natans* from Colombia, Venezuela, and Trinidad. The slenderest caecilian is *Caecilia bassleri* of Colombia, Ecuador, and Peru, in which the total length is 160 times the diameter of the body. On the other hand, one of the lowest ratios of body length to diameter is found in *Typhlonectes compressicauda*, from the Guianas and Brazil, whose length is only 12 times the diameter.



There are no external signs by which we can tell the male caecilian from the female. The male, however, has an intromittent organ for internal fertilization of the female's eggs, and this organ is occasionally extruded under stress. In pregnant females of live-bearing species, the body becomes quite stout and enlarged posteriorly before the young are born. A perfectly formed embryo 3 inches in length, nearly ready for birth, was taken from the oviduct of a female *Gymnopsis parviceps* of Panama, which it will be remembered measures only 7 inches when fully adult. Actual fertilization of a female by a male has not yet been observed by scientists. Some of the American caecilians are supposedly egg-laying, since no developing embryos have ever been found in the female's body; these genera are *Rhinatrema*, *Siphonops*, and probably *Caecilia*. The viviparous ones belong to the genera *Gymnopsis*, *Chthonherpeton*, and *Typhlonectes*.

External gills in the larvae have been reported only once—in *Rhinatrema*. They occur, however, in embryos still inside the egg in *Rhinatrema* and *Siphonops*, and in embryos in the oviducts of *Chthonherpeton* and *Typhlonectes*. No gills have been found in embryos in the oviducts of *Gymnopsis*. The larvae of *Rhinatrema* have three pairs of gills, the two anterior pairs being fringed. In *Chthonherpeton* and *Typhlonectes*, the gills consist of a single pair of large, flat, leaflike structures that are probably entirely embryonic in duration. Females of these last two genera normally give birth to young that are small replicas of the adult, not larval at all. *Rhinatrema* has a true larval stage, presumably aquatic, after the young emerges from the egg. *Siphonops* lays eggs, but it is not known whether a larval stage outside the egg exists. It is believed that *Caecilia* lays eggs.

Most of the American caecilians tend to have subdued colors. They are usually dull blackish above and a little lighter below. The head is a little paler than the back, and the anal region is whitish. In some members of the genus *Caecilia*, the lower surface is mottled with white spots. A vivid yellow stripe extending from the jaw along the sides to the vent exists in three species of *Rhinatrema*.

The American caecilians are certainly carnivorous, like their Old World relatives, but their precise food habits are still unrecorded. They fall victim to several kinds of snakes, as we know from the fact that they have been taken from the stomachs of *Ninia*, *Leptodeira*, *Sordellina*, and several species of *Micrurus*. The photograph of *Siphonops annulatus* (Plate 1) gives a unique clue to the probability that the ever-

present earthworm may furnish at least one element in its sustenance.

Turning now to the Asiatic caecilians, we find four genera, among which the best known is the sticky caecilian, *Ichthyophis*, occurring in southeastern Asia. It grows to a length of approximately 15 inches and is bluish black above, with a bright lemon-yellow band along each side. Its tentacles are white, and the eyes, which are functional, are black with a narrow light-brown ring around them. The sticky caecilian stays in moist places, preferring mud banks near water. Its food consists of earthworms and small burrowing snakes. It lays about two dozen eggs, quite large in size— $\frac{1}{3}$  by  $\frac{1}{4}$  inches—compared to the half-inch diameter of the female. They are connected by a gelatinous string and are deposited in a burrow dug by the female near water. She then coils around them and protects them until they hatch. The young is aquatic and seeks out the water as soon as it is able to move freely. It has a pair of breathing pores on each side behind the head, but no gills remain at the time of hatching. Its head is somewhat like that of a newt, and it has well-developed eyes. The tail is laterally compressed, with an upper and lower dermal fold to aid in swimming. While aquatic it must come to the surface frequently to breathe.

In Bangkok the sticky caecilian is quite common. While digging in a garden near water, workmen dug up five caecilians in a trench thirteen feet long. Their habit of staying underground makes them appear much less common than they really are. During heavy rains they leave their burrows, as otherwise they might be in danger of drowning. After an especially stormy night some can usually be seen lying on the highroad, having been killed by people who thought they were snakes.

The black caecilian, *Ichthyophis monochrous*, is, as its common name indicates, a uniform purplish black, with the tip of the tail and the anal region pale pink. It grows to a length of nearly 20 inches. It is found throughout southern India, Malaya, and the Philippines.

*Hypogeophis* of the Seychelles Islands has a development similar to that of *Ichthyophis*, except that its young do not have an aquatic stage; they leave the egg looking just like their parents and are able to burrow and otherwise maintain themselves from the moment of hatching. The adults choose moist ground for their home, tunneling down to a depth of about a foot. They breed during the greater part of the year, whenever there is sufficient moisture. The female coils around her eggs after laying them, just as *Ichthyophis* does. The clutch numbers from six to about



thirty. As they are not aquatic, no tail fin appears in the embryonic stage.

*Scolecophorus kirkii* from Nyasaland, Tanganyika, and Northern Rhodesia lives in leaf mold on the floor of mountain forests. It seldom crawls on the surface of the ground, even in wet weather. It is said to live largely on termites, but a captive specimen regurgitated a 4-inch worm. It is probably viviparous, although full observations on its life history are still to be made.

*Scolecophorus vittatus* from Tanganyika grows to a length of nearly 12 inches, with a body diameter of  $\frac{1}{3}$  inch. As a defensive gesture it exudes a sticky purplish slime in considerable quantities. A captive specimen had eaten a caterpillar, and probably ter-

mites are also included in its diet. It lives in leaf mold under rotting logs in damp rain forests. The stomach sometimes contains small parasitic nematodes.

A female of *Scolecophorus uluguruensis*, also from Tanganyika, had four embryos in the oviduct. One of these had distinct and well-developed eyes.

*Schistometopum thomensis* (Plate 2) of São Thomé, West Africa, bears its young alive at a very advanced stage. Although known since 1873, it was grouped with the American genus *Dermophis*, but has recently been found to differ in various features. Its color range is from yellow to brown or gray, the first being most unusual in this family of neutral-toned burrowing amphibians. The yellow phase is well shown in Plate 2.

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## PART TWO

# The Salamanders

(Order Caudata)

**S**ALAMANDERS belong to the second main division of the class Amphibia. They are much less noticeable to the average person than the frogs and toads, as they are voiceless or nearly so, emitting at most a small squeak when handled. All of them are secretive and fond of hiding in out-of-the-way places, and hence are seldom to be seen without considerable searching.

They have somewhat the same geographical distribution as the frogs, except that no salamanders occur in southern South America, most of Africa, all of Australia, and the Malay Archipelago. Their physical needs are very much like those of frogs—moisture at all times to lubricate their porous skins, standing fresh water in which many kinds lay their eggs at

breeding time, damp humus for the land dwellers, and plenty of insects or worms on which to feed.

While individuals of certain species are often very abundant in an especially favorable region, the total number of kinds of salamanders is far less than that of the frogs. There are only about 60 genera of living salamanders, belonging to 8 different families, while some 225 species and subspecies are known at present. The study of these shy little animals is now very popular. Salamanders are kept alive for observation under a multiplicity of controlled conditions in nearly every zoological laboratory in the world. In their larval stages they serve as the basis of transplantation experiments, pituitary and thyroid feedings, and almost every other imaginable experiment that can

be made by changing the chemical or physical constituents of the environment. They are a favorite laboratory subject, since many kinds are relatively easy to obtain in quantity and since their natural habitats can be duplicated in the laboratory, so that they can be kept alive until required.

Most salamanders are terrestrial, living under forest debris just at the surface of the ground. In dry weather they retreat as far as possible into a convenient hole or crevice in their effort to find the moisture necessary to sustain life. A few kinds are arboreal, living in bromeliads (plants growing in trees) in tropical forests or in knotholes in trees in temperate zones. Some are aquatic, and never leave the water. Still others live in caves their whole lives long and have become nearly or entirely blind, since eyes are not needed in the total darkness of a cave habitat.

An elaborate ritual of prenuptial behavior is known in many groups of fishes. Anyone who has kept a tank of guppies has seen the male spread his fins and tail and flaunt their glowing colors before the eyes of the female, swimming back and forth in front of her in what seems almost like a rehearsed performance. Mating usually takes place during this swimming dance, and thus the purpose of the whole display is fulfilled.

Most salamanders likewise go through a complicated display in front of the females at the breeding season. The male's activities at this time seem to stimulate the female's willingness to pick up the spermatophores. It may also prevent cross-breeding, since each kind of salamander has its own pattern of courtship, to which no female of a different species will respond.

Salamanders are of little economic importance to man. Their legs are small as a rule, and hence are not such a gastronomic treat as frogs' legs. But the larger aquatic forms were probably eaten by primitive tribes in both the Old and the New Worlds; in fact, the "axolotl," the larval stage of a member of the family Ambystomidae, is cooked and sold as a delicacy to the natives of Mexico City, near which it is abundant.

In their foraging for small insect prey, salamanders undoubtedly destroy many pests, but they also probably take as many helpful insects. Their use in the laboratory in studying limb regeneration and transplantation of tissues has already been mentioned. Their variety of color and the rich translucence of their skins make them a subject of aesthetic appeal to anyone who takes the trouble to look at them carefully. The number of persons who study their habits and keep them as pets has grown by leaps and

bounds during the past quarter of a century, probably because the growth of urban communities has pushed out the boundaries where wild creatures may be seen at large.

## The Hynobiids

(Family Hynobiidae)

The family Hynobiidae is confined to Asia, but some scientists have thought that it is related to the Cryptobranchidae, a family now found in both Asia and North America, and also to the exclusively American family Ambystomidae.

The Hynobiidae are the only salamanders except the Sirenidae and Cryptobranchidae in which fertilization is external. This is considered to be the most primitive method. In these three families, the females lack the cloacal sperm receptacle that is present wherever internal fertilization occurs.

Salamander eggs of two kinds are known—the apparently primitive sort that is pigmented and has a small yolk, called the vitellus, and the kind laid by presumably more advanced groups, which is not pigmented and has a large vitellus. The Hynobiidae, as well as the anatomically primitive members of some other families, lay eggs of the first sort and abandon them in the water without making any attempt to hide them. The pigmentless eggs of the more highly organized salamanders are often laid in "nests" among debris or are otherwise concealed where they are not likely to be found and eaten, while one of the parents usually lingers nearby until they have hatched.

Among the Hynobiidae, all the genera lay their eggs in paired sacs. *Hynobius*, the least specialized of the genera, produces in each sac thirty-five to seventy eggs, which are laid in stagnant pools or slow, sluggish streams.

They are among the most primitive of the living Caudata, as is indicated not only by many structural features but also by their mode of reproduction. The males are the first to come out of hibernation in the springtime; they then go to the water, followed in a day or two by the females, which soon lay their two sacs of eggs. In *Hynobius lichenatus* the female attempts to glue the first of the egg sacs to a submerged rock. She then backs away in order to release it fully from her oviduct. The males have paid no attention to the laying female up to this point, but now they rush forward to seize the egg sacs with their front legs while they push the female away with



their hind legs. The males rub the sacs with the edges of their cloacas, thus fertilizing them externally with the sperm released onto them as they are being extruded, while the movements of the hind legs help in delivering the eggs from the female's body. After all the spawn has been deposited and the female has gone off to hide, the males still continue to cling to the eggs for a short period.

The genus *Hynobius* has the widest distribution of the five genera making up the family, as its members are found from Japan to northern Siberia, Turkestan, and the Ural Mountains.

*Hynobius shihi*, known to science only since 1951, is from eastern Szechwan. It has gone a step toward neoteny, since the mature adults possess gill stumps covered by skin, although their lungs are unusually well developed. When further life-history studies of this interesting species have been completed, it may turn out to be truly neotenic—that is, laying eggs in its larval stage.

*Pachypalaminus* is known from a single species, with a range limited to Yamoto, in Hondo, Japan. It differs from *Hynobius* in having the palms of the hands and the soles of the feet, including the tips of the digits, covered with a horny skin.

*Randon sibiricus* comes from Chinese Turkestan. It has feet similar to *Hynobius* but teeth somewhat like those of *Batrachuperus*. It lives in mountain brooks and consequently has much diminished lungs. It grows to a length of  $8\frac{1}{4}$  inches; in one of this size the lungs were only  $\frac{7}{8}$  inch long.

The most specialized genus is *Onychodactylus*. It is known from Korea to Hondo and Shikoku, Japan. Its two species are lungless. *O. japonicus* lives near mountain streams, hiding under mist-drenched rocks. The tips of the digits in the larvae have sharp, curved claws, which are sometimes retained into the adult stage. Smaller but similar claws are found in *Hynobius peripus*.

The last genus, *Batrachuperus*, occurs from Szechwan, China, to the Khan province, Tibet. It lacks the fifth toe; in fact in all the Hynobiidae this toe is variable in length, and is absent also in *Hynobius keyserlingii* and usually in *Hynobius kimurai*. *Batrachuperus* has horny pads on the feet, as in *Pachypalaminus*, but has a different arrangement of teeth on the vomer (one of the bones forming the roof of the mouth).

The sense of hearing is probably not very acute in these salamanders. The structure of the ear suggests

Hellbender (*Cryptobranchus alleganiensis*). John H. Gerard







Eggs of Hellbender (*Cryptobranchus alleganiensis*).  
Charles J. Stine, Jr.

that the larvae receive vibrations through the lower jaw while they are resting on the bottom of the pond. The adults seem to receive such vibrations entirely from the forelimbs. The lateral-line organs probably take the place of ears as a warning mechanism, since vibrations of low frequency transmitted through the water are known to stimulate these organs.

*Batrachuperus pinchonii* is truly a salamander of the heights, for it occurs at elevations between five thousand and thirteen thousand feet in the mountains of Sikang and Szechwan, China. It is entirely aquatic, being found in the water or under stones near the margin of icy mountain streams. The larvae and very young ones like to frequent the places where cold springs emerge from the ground to form the headwaters of streams.

Another closely related salamander, *Batrachuperus karlschmidti*, also from Sikang and Szechwan, figures in the folklore of the region. There is a temple near the White Dragon Pool at the top of Mount Omei sacred to the worship of this salamander, which is called "white dragon" by the monks and inhabitants of that region. They believe that the King of the White Dragons lives in this pool and that if someone kills one of the salamanders, a fierce storm will follow at once. In spite of this belief, some of these salamanders are captured by the herb collectors, killed, dried, and sold to the local "drugstore" as a cure for stomach trouble. The patient seeking medicine for a stomach ache is told to grind the salamander to powder and drink it in boiling water.

Several other salamanders of this genus also occur in southern China, but it is not known whether such magical powers are attributed to them.

## The Giant Salamanders

(Family *Cryptobranchidae*)

The largest of all living salamanders belongs to this family. It is the giant salamander of Japan, *Megalobatrachus japonicus*, which grows to a little over 5 feet in length. The Japanese fishermen find it rather easy to capture with a hook and line, and its flesh is relished as part of the human food supply.

The first living example of the giant salamander was brought to Europe by Philippe François de Siebold, its discoverer, in 1829. This individual died in 1881, having lived for fifty-two years in captivity.

A captive specimen, while entirely aquatic, must rise to the surface to breathe air every six to ten minutes. It waits on the bottom of its tank for its prey to come near, then seizes it with a swift sidewise movement of the head. In its native mountain streams it feeds on fish, other salamanders, worms, and insects. Its eggs are deposited in a rosary-like string during August and September. The young on hatching have three pairs of short branchial processes, but when metamorphosis is complete, these and the gills have disappeared.

The Chinese giant salamander, *Megalobatrachus davidianus*, was discovered by Père David, one of the Jesuit priests who first made a biological survey of China. It is not as long as its Japanese relative, but still attains the quite impressive length of 41½ inches. It is distinguished from the Japanese form by the arrangement of the "barbels"—curious little beadlike appendages under the chin. The pupils of Confucius regarded it as a lizard, but in Shensi it was referred to in literature of two hundred years ago as a "man-fish."

The North American representative of this family is the hellbender, *Cryptobranchus alleganiensis*, found from New York State to Alabama and westward to Arkansas in rivers and large streams in which the water flows rather rapidly, hence is well aerated. Its maximum length is slightly over 29 inches. Its food consists of almost any water animal of a size that can be swallowed, as well as snails, fish eggs, aquatic worms, and even dead bits of animal matter.

In the swift water the female has a most ingenious way of ensuring the safety of her eggs. These are laid in long, gelatinous strings, like small marbles spaced at regular intervals along a chain. The sticky egg casing is pushed by the mother into firm adherence with a submerged stone or log on the river bottom. The casing hardens on contact with water, so that it



becomes quite firm and remains where it has been placed. The young hatch in from sixty-eight to eighty-four days. At first their bodies are less streamlined than those of the adult. After they have exhausted their munificent supply of egg yolk, they begin an existence of alternately swimming against the river current and nuzzling the mud on the bottom of the stream in search of hidden tidbits such as worms and crayfish.

## The Mole Salamanders

(Family Ambystomidae)

During a springtime collecting trip to the banks of the Patuxent River in Maryland, I was examining a wild orchid when I discovered a marbled salamander under the leaves. He had silver saddle-like markings on a shiny black background, and beady black eyes, and his hands were almost human-looking with their four long fingers. I put him into a moss-filled box in my collecting kit, and a few hours later he was in my vivarium at home. I fed him earthworms and soon made a "pet" of him, so that I could observe and record his activities.

Most of his days—especially the bright sunny ones—were spent in seclusion under a heap of flat stones loosely piled in a corner of the cage. As night came

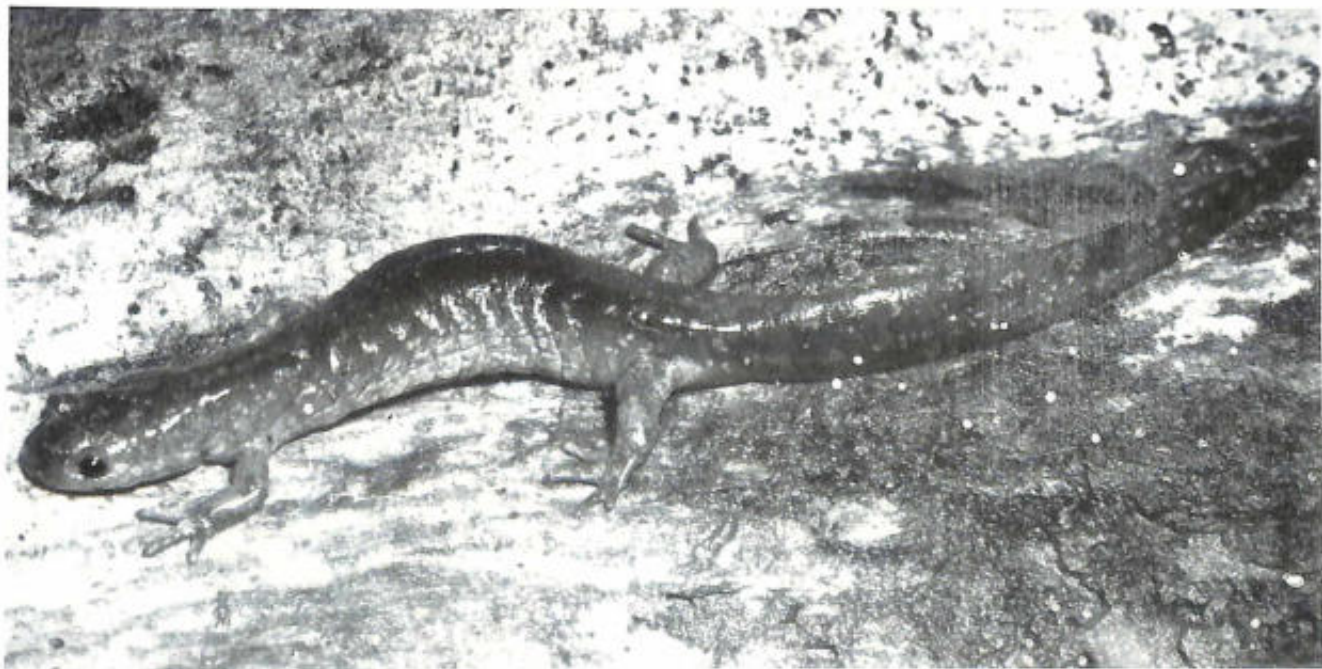
on, he would sally forth for a foraging expedition. He seemed to like to stalk after the little isopods—pill bugs—that I found under old flower pots in the yard and dropped into his cage. Small slugs and insect larvae were also taken, but the highlight of his night's hunting appeared when he came upon an earthworm.

The salamander does not use his hands to help push the prey into his mouth, as many frogs do, but must manage the seizing, holding, and swallowing of a slippery, struggling worm by the grip of his jaws and tongue alone. Thus he has rather strong jaw muscles for closure of the mouth, and a short, non-extensible, mushroom-shaped tongue which can be pushed vigorously upward against the roof of his mouth, to help in subduing an overactive mouthful of worm and in propelling it into his gullet. He also has a little band of "teeth" around the rims of the upper and lower jaws—not teeth for chewing such as mammals have, but fine, almost brushlike bristles that give him a better purchase on the wriggling slug or worm.

The marbled salamander, *Ambystoma opacum* (Plate 4), is quite terrestrial in habit, more so than some of its close relatives, being frequently found on hillsides near ponds and streams. The species occurs from New England to northern Florida and westward to Texas. It does not exceed 5 inches in length.

It breeds in the fall, unlike most of its close rela-

Jefferson salamander (*Ambystoma jeffersonianum*). Karl H. Maslowski





tives. Fertilization is internal. The female deposits her eggs—between fifty and two hundred at a time—in some shallow depression in the forest floor, and remains with them until the next good rain comes along and covers them with water. With sufficient moisture the eggs soon hatch, but if rain is lacking, they remain unchanged until the following spring. The fall-hatching larvae are ready to transform early the following summer, when they have grown to 2½ to 3 inches. They are sexually mature about fifteen months later.

In most other members of this genus, the males display a true pattern of courtship in the water, going into a sort of dance that is started by the appearance of the first female at the breeding pond. The males swim back and forth, turning about each other and rubbing their noses along each other's bodies and

capsule by the lashing movements of their long tails, as well as by a digestive substance that penetrates the egg capsule. As soon as the first spermatozoan has reached the center of an egg, the fertilization reaction begins, and at once a membrane forms to prevent the entrance of other spermatozoa.

In axolotls, both sexes engage in the courtship ritual, the females nosing the abdominal glands of the males, seeming to be attracted by their secretion. Often the male fans his tail in a female's direction, presumably to send the odor of this secretion toward her through the water.

The spotted salamander, *Ambystoma maculatum* (Plate 3), breeds in the more usual time of very early spring. At other seasons of the year one can seldom find any of these creatures without a long search, but in the middle of March they begin to flock to their



Spotted salamander (*Ambystoma maculatum*). Maslowski and Goodpaster

tails, and sometimes heaving one another upward by thrusting their heads under each other's bodies. A secretion is also emitted from their hedonic glands. These actions entice the female to take up the mass of spermatophores that the male has deposited. This she does by swimming or walking on the bottom of the pond until the mass is directly below her cloaca. Then the edges of the cloaca are parted, to close on the sperm mass. The small sperm cells, called spermatozoa, eventually travel upward to the female's oviduct, where her unfertilized eggs lie. The spermatozoa make their way through the gelatinous egg

favorite breeding ponds by the dozens, sometimes by the hundreds. A warm spring rain seems to trigger their impulse to procreate, and soon the ponds are filled with a milling mass of black-and-yellow bodies. In a day or two there will be dozens of pale balls of tapioca-pudding-like eggs lying in the water, but no salamanders remain, as they have all gone back into hiding for another year.

Sometimes the egg clumps take on a lovely pale green tint, as symbiotic algae often live among the eggs without doing them any harm. But woe to the developing larvae if some of the eggs should suddenly

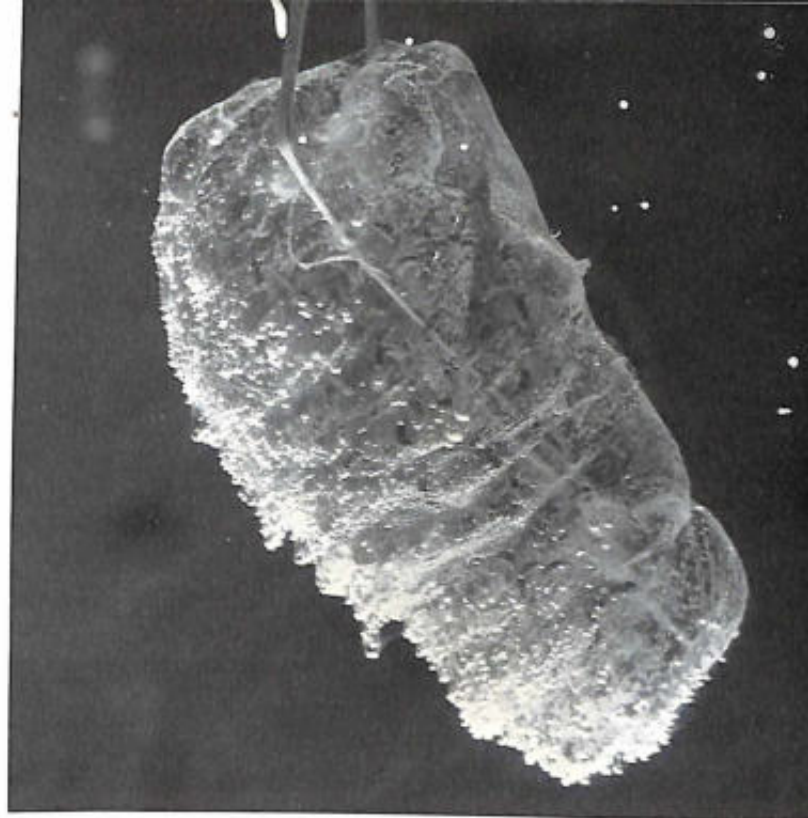


turn an opaque white! This is the sign of an attack by a lethal mold, *Saprolegnia*, which can quickly invade the whole cluster of eggs and wipe out all the larvae in it. Some egg masses in nearly every pond escape this premature death, however, and after an incubation period of from 31 to 54 days, the water swarms with half-inch-long larvae assiduously nibbling on the microscopic life which at this stage serves them as nourishment. After their gills have been absorbed and their metamorphosis is complete—usually in from 61 to 110 days—they leave the water to become land dwellers, hiding under stones or logs, or in shallow caves where there is always the necessary moisture. On leaving the water they are 2 to 3½ inches long, and a very large adult will measure 9 inches in length. They range from Nova Scotia to Texas, thus being found in about the same areas as the marbled salamander.

The eastern tiger salamander, *Ambystoma tigrinum*, may reach the imposing length of slightly over 13 inches, making it the largest terrestrial salamander in the world. It has yellowish or light olive bars, not nearly so brilliant a yellow as in the spotted salamander, however, but probably suggesting its popular name. It likes to lay its eggs in deep-water ponds, and, if there be no fish present to devour them, its larvae may be found in such bodies of water from Long Island to Florida and westward to the Mississippi, in lowland ponds only, as it avoids the high parts of the Appalachian chain.

In all the eastern tiger salamanders, metamorphosis is complete after a few weeks or months of larval life, and the adult spends the rest of its life as a terrestrial animal. But in most western subspecies of the tiger, metamorphosis often fails to take place, the creature becoming neotenic—that is, breeding while in the gilled stage. The chief cause of this condition is believed to be insufficient iodine in the diet, as most lakes in Colorado, Wyoming, and Mexico are deficient in iodine. It has been proved experimentally that a larval salamander from which the thyroid gland has been removed will not metamorphose unless it is fed upon thyroid extract. In semi-desert areas, the failure to metamorphose is often a lethal factor, since many of the shallower ponds dry up, killing hundreds of larvae which would normally have completed their larval life and have left the ponds long before the arrival of the dry season.

The frosted flatwoods salamander, *Ambystoma cingulatum*, gets the first part of its name from the lichen-like grayish dorsal markings on its black ground color, suggesting the frost "leaves" on window panes during winter. The second part of its

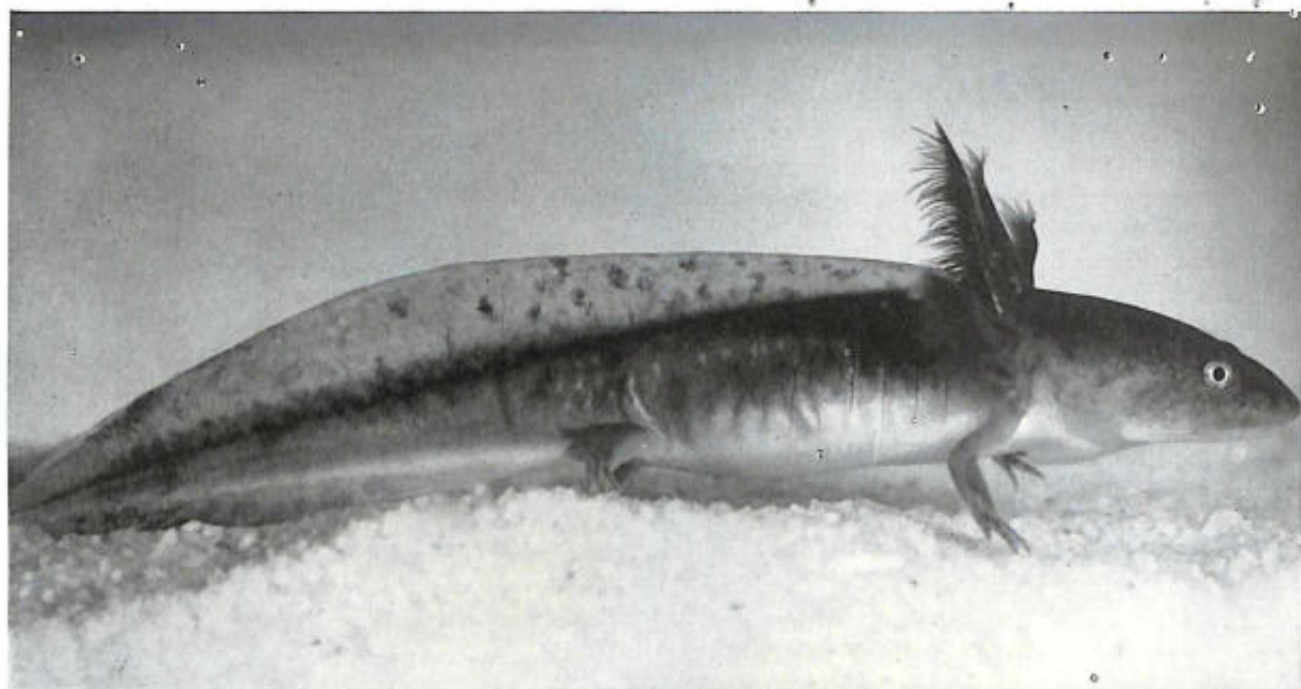


Eggs of Tiger salamander (*Ambystoma tigrinum*).  
Charles J. Stine, Jr.

Axolotl (*Siredon mexicanum*), albino.  
Ralph Buchsbaum







Larva of Tiger salamander (*Ambystoma tigrinum*). Charles J. Stine, Jr.

name refers to its dwelling place in the slash pine and wiregrass flatwoods between North Carolina and northeastern Florida. Its maximum size is 4½ inches.

The ringed salamander, *Ambystoma annulatum*, is to be found only during or after rains, when the moisture stimulates its breeding instinct. It congregates, sometimes by the hundreds, in pools and shallow ponds at such times. The rest of the year it is quite difficult to find. Its range extends from central Missouri to western Arkansas and eastern Oklahoma. A large adult may reach a length of 8 inches.

The Pacific giant salamander, *Dicamptodon ensatus*, occurring in damp coastal forests from British Columbia to central California, grows to a length of nearly 12 inches, and has a heavy, ungainly build, unlike that of the smaller and more graceful members of its family. In spite of its clumsy appearance it can climb quite well, as it has been found several feet above ground on sloping tree trunks and even in low bushes. Another peculiarity is its ability to make a noise when disturbed, the sound being variously described as a "bark," "scream," or "low-pitched rattling."

This salamander eats nearly any kind of animal of a suitable size. Snails, slugs, worms, beetles, and other insects are to be expected in a salamander's diet, but the Pacific giant also takes other salamanders, small snakes, and even mammals such as shrews and mice

when it can find them. It is largely nocturnal but may sometimes be seen by day, even in bright sunlight.

While the actual laying of eggs has not yet been reported in this species, a nest of about a hundred eggs was discovered during excavations, buried twenty feet deep in a sandstone hill where the female had apparently followed a deep crevice from a cold spring seepage to reach this underground site. One California scientist who had some Pacific giant salamanders in a gravel-floored terrarium in his bedroom claims he was kept awake at night by the scratching of his pets in their attempts to bury themselves in the gravel.

The Olympic salamander, *Rhyacotriton olympicus*, lives in the coastal forests of Washington, Oregon, and northwestern California. Its adult length is 4 inches. Like the Pacific giant salamander, it prefers to stay on land among loose pebbles in spring seepages, and in the shallows of cold streams. It is very alert, and if disturbed on land, it quickly plunges into deep water and swims away, using lateral movements of the body and tail in swimming. Its lungs are reduced to tiny structures less than ¼ inch long, but they retain circulation and are filled with air in breathing.

It should be added that Mexico has a sizable population of ambystomatid salamanders, some of them neotenic.



## The Newts (Family Salamandridae)

The Old World newts of the genus *Triturus* were among the first of the salamanders to be critically studied by a scientist, the master naturalist Linnaeus having known and described the smooth newt, *Triturus vulgaris*, in 1758.

Although terrestrial during the greater part of the year, the European newts become aquatic during the breeding season. The male newt at this time is one of the most delicately beautiful of all living creatures. The fins of the tail and the dorsal crest become enlarged, frilled, and colored red along the edges, contrasting with the black-spotted brown body. An elaborate nuptial display is staged by the male for the female's benefit. First he moves with abrupt, springy movements through the water until he has found a female, whom he then follows, putting his nose against her sides, and even upon her mouth in a gesture resembling a kiss. She keeps on her way at first, but he persists in following her, and finally tries to stop her progress by taking a position in front of her and displaying all his finery. His tail vibrates, shaking its frilly crest into a continuous pattern of movement and color, while he curves his body into sinuous shapes as he swims in front of her. All this

is a prelude to his deposition of the spermatophores, which he finally places in two or three little clusters on the bottom of the pond. If the female is not prepared to accept them, she swims away, but if ready, she walks over a spermatophore clump and picks it up by pressing her cloaca over it. Inside her body the tiny sperm cells travel upward to the organ which receives them on their way to fertilize the eggs. After this, the female will not accept any more spermatophores until these eggs have been laid. She glues these singly or in small clusters to the stems of water plants or to stones. The eggs hatch in about two weeks. Metamorphosis is finished by the end of summer, the small newts coming onto land to hide in crevices under stones.

Ecdysis, or shedding of the skin, is easier to observe in the thick-skinned newts than in most other kinds of salamanders with lighter skin structure. Since the skins of amphibians do not stretch to accommodate the growth of the body, a new and larger skin periodically forms just beneath the old outer one, which latter subsequently splits, usually around the mouth. By contortions of the body, assisted by its fingers, the newt manages to slip the old skin backward over the body and finally off the tail, after which it tidily swallows its cast-off skin. In the thinner-skinned aquatic

Smooth newt (*Triturus vulgaris*). Wilhelm Hoppe





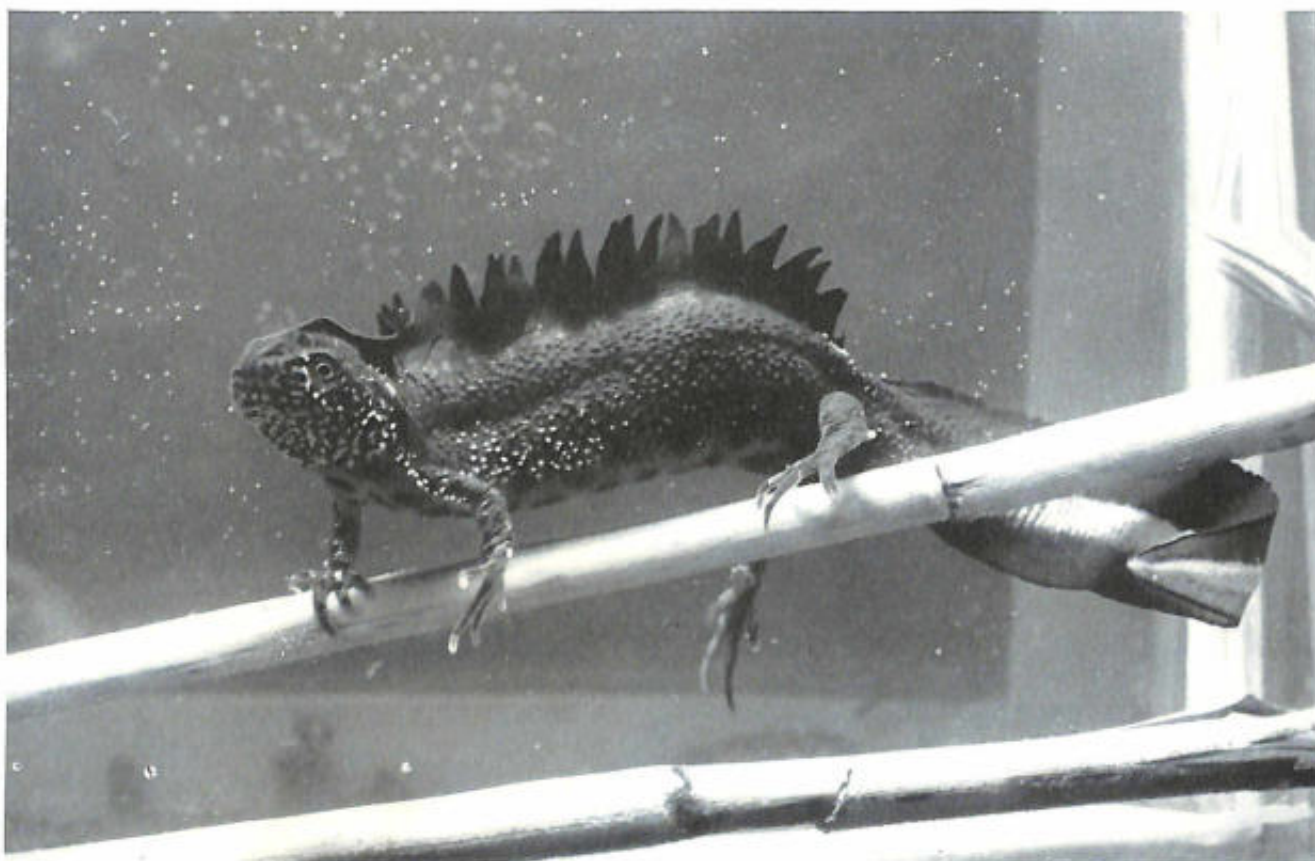
salamanders, the old skin is more likely to float off in small pieces, so that the shedding process is seldom observed from start to finish. The smooth newt, *Triturus vulgaris* (Plate 7), has a very wide range, being found in most stagnant pools from central France to the Ural Mountains and Constantinople. The male in the full splendor of his breeding attire is shown in this plate.

Several kinds of newts of the genus *Triturus* are known from Europe, while one species extends into North Africa in oases and other well-watered regions.

The warty newt, *Triturus cristatus*, is the largest of all European newts, attaining a maximum length

of nearly 6½ inches for the female and 5¾ inches for the male. It grows quite rapidly for its first four years and much more slowly for the remainder of its life. Those whose growth is checked because of food shortage or for any other reason during their early years never attain the large size of individuals that develop at a normal steady rate.

The common fire salamander, *Salamandra salamandra*, has probably been a subject of superstitious veneration ever since the days of the cave men, one of whom probably first saw it crawling away from a log which he had just thrown upon the fire, and so assumed that it was born of the flames, hence mysterious and perhaps baneful. The salamander with flames around it served as the crest of one of the royal families of France.



Warty newt (*Triturus cristatus*). Erich Sochurek

usually in July, and in about ten months the female enters the water and bears her young alive, without any egg stage outside the mother's body. There are ten to fifty young in a litter, each about an inch long, and having the arms and legs well developed. Branchial gills are present, however, marking the little creatures as true larvae. After metamorphosing, they become terrestrial for the balance of their lives.

The fire salamander is unusually well protected

The fire salamander is unusually well protected

The fire salamander is unusually well protected







from its would-be enemies by the poisonous secretions of its skin. When handled gently it is quite harmless, but when it suffers rough treatment its skin glands secrete a fluid which causes a burning pain in the mouth of its captor, and which may cause death in a small mammal.

While most salamanders are more or less solitary by nature except during the breeding period, fire salamanders are quite gregarious, several adults often sheltering together in a favorite hiding place. Their love of company may be their undoing, for there is a serious disease—*Molgepeste* as the Germans call it—fungoid in origin, which attacks and kills these salamanders. Being highly infectious, it may be transmitted from one animal to all the others that come in contact with it in their communal hiding place. Modern science can control this disease in laboratory animals, but free-living salamanders must run the danger of infection during the whole of their short lives.

Fire salamander (*Salamandra salamandra*).  
Ernst Zollinger



As very few animals die of old age in the wild state—being captured and eaten by something as soon as their powers of escape have slackened in the slightest degree—we seldom get a true idea of their maximum age possibilities by tagging or otherwise marking wild individuals in their natural habitat. But in the laboratory or home “zoo,” under ideal conditions in a vivarium simulating its known requirements, the fire salamander has been known to live for twelve years in good health.

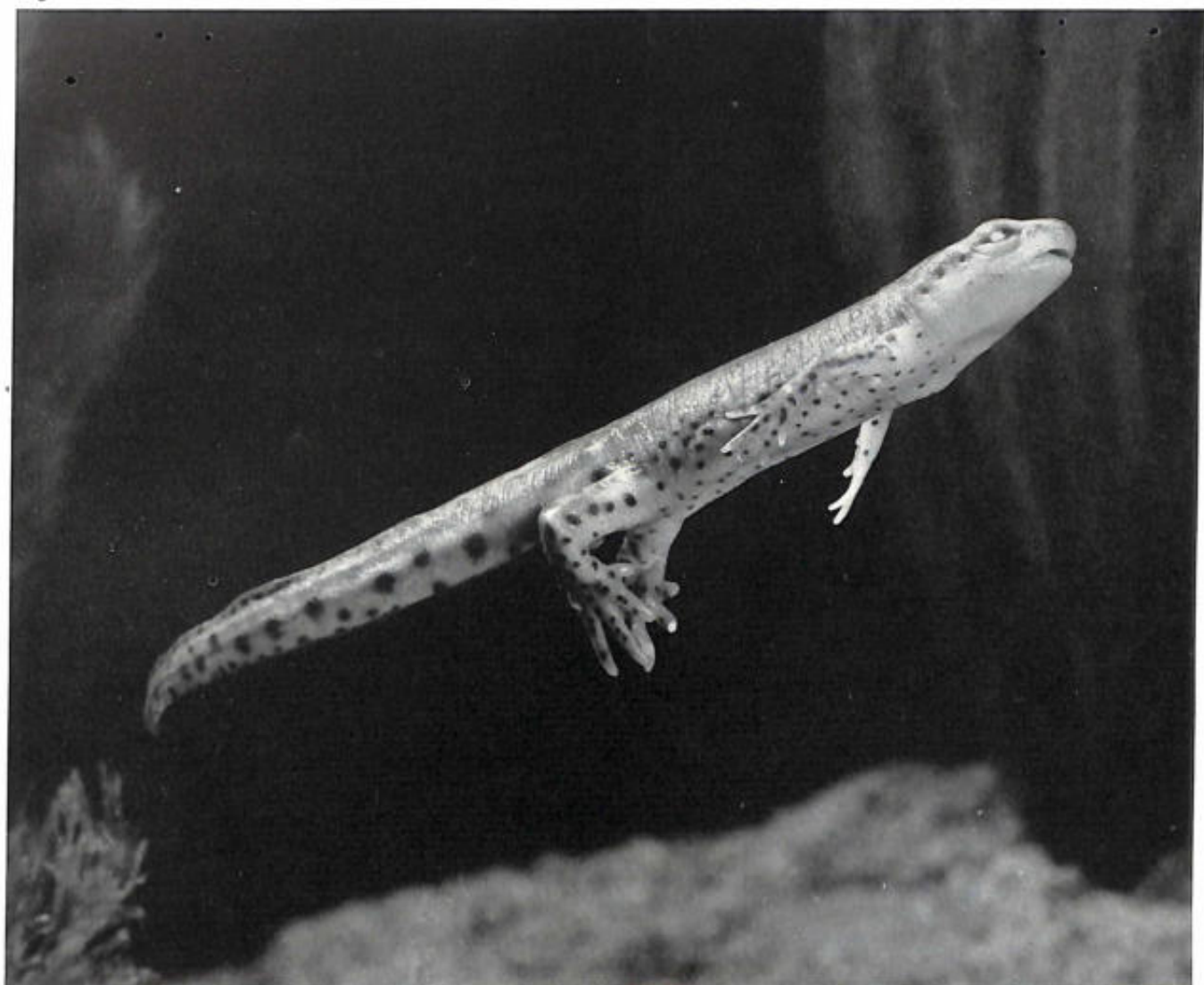
Several other interesting genera of this family live in Europe, Asia, and North America. The red-spotted newt, *Diemictylus viridescens* (Plate 5), of the eastern United States, has a terrestrial form called the “red eft stage.” After living on land two or three years, these bright red salamanders re-enter the water and become permanently aquatic adults with a quite different coloration of dull green with a row of small red dots along each side.

One of the handsomest of the North American forms is the broken-striped newt, *Diemictylus dorsalis*, occurring on the coastal plain of the Carolinas. Its habits are similar to those of its close relative, the red-spotted newt, but it is a trifle smaller, not exceeding  $3\frac{3}{4}$  inches in length.

The California newt, *Taricha torosa*, lives in the coastal ranges of California between Mendocino County and San Diego County, usually in ponds. It can live on land, however, and does so when the ponds dry up in summer. When the winter rains have refilled the ponds, breeding takes place. At this season the usually granular skin of the males becomes smooth, the tail broadens and develops a high fin, and the cloaca enlarges. Males congregate first at the breeding ponds, and as each female makes her appearance a little later she is surrounded by a writhing ball of males. The successful suitor straddles the female, with his arms clasped around her body just below her armpits. He swims about with her, meantime rubbing his cloaca over her back and also stroking her snout with his chin, on which a gland is located that stimulates the female to accept his courtship. The male leaves the female and deposits his spermatophores on the bottom of the pond in front of her and she then walks forward and picks up the spermatophores with her cloaca. There are between seven and twenty-nine eggs in a cluster, and they hatch in about fifty-two days. The newly metamorphosed young come out on land, as they drown if forced to remain in the water. They are sexually mature in their third year.

Newts of the genus *Pleurodeles*, from Spain, Portugal, and northern Africa to French Guinea, have





Red-spotted newt (*Diemictylus viridescens*). Robert E. Lunt: Annan Photo Features

long pointed ribs that frequently perforate the skin, their tips being visible in the living animal. This condition apparently causes no inconvenience, as the Walzl newt, *Pleurodeles walzl*, has been known to live for twenty years in captivity. Poirer's newt, *Pleurodeles poireti* (Plate 6), about 5¾ inches in length when full grown, has the third and fourth toes unusually long compared with those of other members of the family. Not much is on record concerning its habits or life history.

This family has an unusually wide distribution for salamanders, some genera also being found in China, Japan, and the Ryū Kyū Islands.

The Japanese newt, *Cynops pyrrhogaster* (Plate 8), is the salamander par excellence for the novice

at pet-keeping. It may live for years in captivity, and may be purchased at nearly every large pet shop, at least in North America and in Europe. Its attractive color and interesting activity when swimming and feeding make it one of the most rewarding to observe of all small captive amphibians.

## The Amphiumas

(Family *Amphiumidae*)

Only two salamanders of the family *Amphiumidae* are known. In outward shape they are rather similar to true eels, which belong among the fishes. In fact,





Red-spotted newt (*Diemictylus viridescens*), red eft stage. Jack Dermid

a common name given to the two-toed amphiuma in some regions is "Congo eel." But a closer inspection reveals at either end of the enormously elongate body minute, useless arms and legs, which no eel possesses, and a different kind of head and tail, while the skin is smooth and sleek, not roughened by small, rasping scales, as in the eels.

The two-toed amphiuma or "conger eel," *Amphiuma means*, grows to a length of nearly 3 feet. It is found in rivers and streams from Virginia to southern Florida. From the Gulf states westward to Texas it intergrades with the three-toed amphiuma, the other member of this weird family. Its color is a dark grayish brown above, gradually fading to a slightly paler slate color on the sides and belly, which probably renders it almost invisible among the water weeds in which it lives. It is nocturnal, and by day hides in the burrows of crayfish or in matted weeds. In wet weather it may stay beneath scattered logs at the water's edge. It apparently returns to the same

retreat after each night of foraging for crayfish, snails, and other small live creatures. It is quick to defend itself, unlike most salamanders, and can bite viciously with its sharp teeth.

Little is known about the breeding habits of the two-toed amphiuma. It has been known to lay eggs, with as many as forty-nine in a single clutch arranged singly like beads on a long string of gelatinous material. The incubation period is supposed to be about five months, as some eggs probably laid in January are known to have hatched in June. The larvae are a little over 2 inches long on hatching, and their legs are of more use to them in paddling about the bottom of the stream than they are in later life when the creature is adult. Metamorphosis apparently takes place when the amphiuma is about 3 inches long, since young ones without gills have been found of that size.

The three-toed amphiuma, *Amphiuma tridactylum*, gets a little larger than the preceding species,



reaching a length of about 40 inches. Its color is more definite on the sides, as there is a sharp ending of the dark dorsal color rather than a gradual merging with the lighter ventral tone, as is the case in the two-toed amphiuma. It occurs from Alabama to Texas and up the Mississippi to Tennessee and Missouri.

The female is known to incubate her eggs, choosing a small depression beneath a log or stone on the bed of a swamp. The eggs are  $\frac{1}{3}$  inch in diameter, and are also laid in a single long string. Some eggs of this salamander have been found in fairly dry soil at the bottom of drying pools. Just how much desiccation they can stand without harm has not yet been accurately determined.

## The Lungless Salamanders

(Family Plethodontidae)

This family has more genera and species than any other among the salamanders. In North America alone there are eighteen genera, and with tropical America's quota added, the family can boast of at

California newt (*Taricha torosa*). Robert S. Simmons

least twenty-five genera, including some 150 species, in the New World, while one genus occurs in Italy. The smallest ones measure about  $1\frac{1}{2}$  inches in length when adult, while the largest are about  $8\frac{1}{2}$  inches. Some live in the water, while others pass their entire lives, including the larval stage, on land. The mothers sometimes incubate their eggs with the faithfulness often attributed to animals much higher in the evolutionary scale. None of the plethodonts have lungs, hence breathing is done entirely through the skin and the mouth lining. Another peculiarity of this group is that the lower jaw is immovable although it is hinged and attached in the usual manner; hence it is the upper jaw—and consequently the whole top of the head—which move upward when the salamander takes a bite of food. Since the tiny teeth are often diagnostic in making correct identification of a preserved salamander, be sure not to force the lower jaw down, as you may break your specimen. Instead, insert a toothpick and raise the upper jaw. Then the mouth usually opens easily, so that the teeth may be examined with a hand lens.

The dusky salamander, *Desmognathus fuscus*, is known from most of eastern North America from New Brunswick to northern Georgia and Alabama, and westward to Oklahoma and Texas. It may be





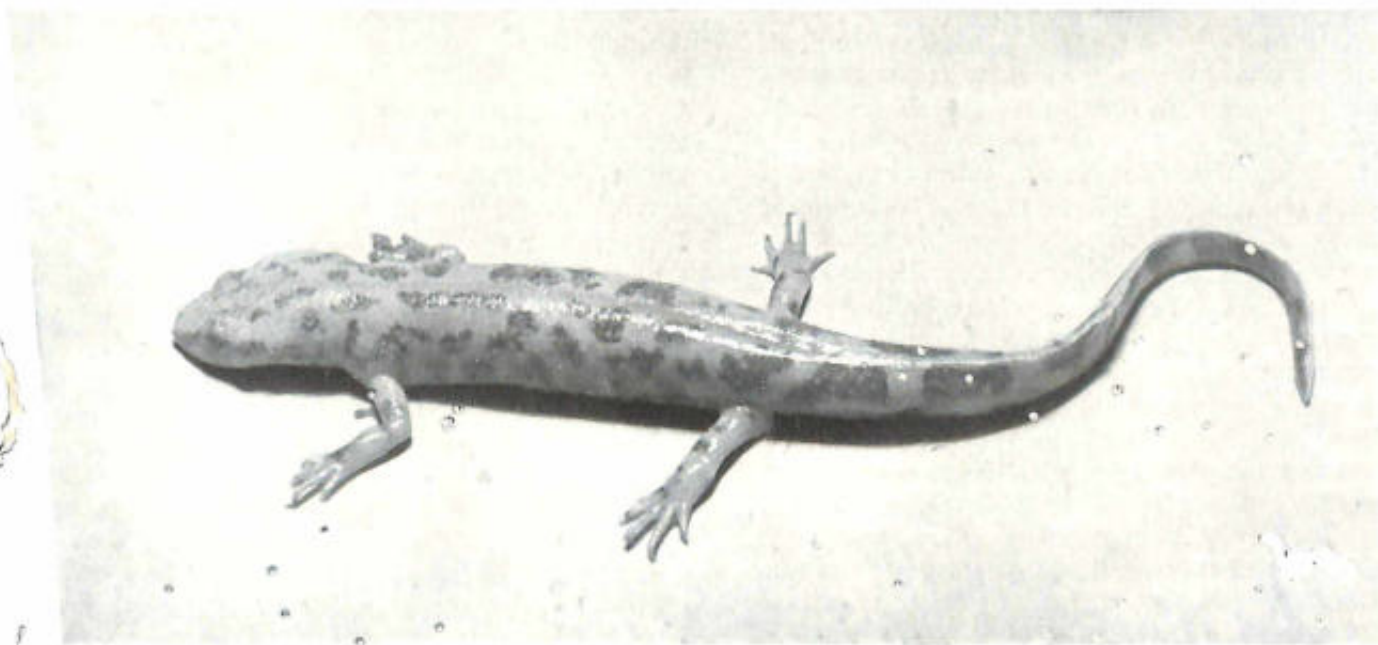
found rather easily under leaves beside streams, in the seepage of springs, or wherever the soil holds a good deal of moisture. The old adult, which reaches a maximum size of  $5\frac{1}{4}$  inches, is dark brown or gray, with scarcely any pattern; a young adult may have an irregular lighter band down the back and a light diagonal line from the eye to the angle of the jaw, but sometimes a paler individual with tan coloring is encountered. The very young one is more brightly marked, with brick-red spots alternating with light cream-colored areas, rather like the pattern of an Argyll sock. Thus the appearance of the salamander changes considerably with age.

At breeding time the male literally rubs noses with the female, as he possesses a gland on his chin with which he stimulates the female to pick up the spermatophore he has just deposited. After being fertilized internally, the eggs are laid in clusters of about two dozen, in late spring or early summer. They are incubated by the female in a hiding place under a stone or fallen tree in some moist location. Each egg is  $\frac{1}{8}$  inch in diameter, and is protected by three jelly-like envelopes, bringing the total diameter up to nearly  $\frac{3}{16}$  inch. The young are about  $\frac{5}{8}$  inch long on hatching. They are quite brilliantly colored compared to the adults, as the back has two rows of round tan spots on a reddish chocolate background. Little gills decorate the sides of their necks, for they must enter a nearby stream for the duration of their larval life. After passing the winter in the deeper unfrozen water of the

stream, they are ready to transform at the return of warm weather. Now they again seek the land, this time for their permanent habitation. In moist trickles from springs and in mats of fallen leaves they may often be found in considerable abundance, for they are gregarious, seeming to like to pile on top of each other in the dark and damp nook which they have chosen. They emerge usually at dusk to hunt for earthworms, small slugs, isopods, soft-bodied insect larvae, and such fodder. On cloudy or rainy days they are also inclined to go hunting, but the bright, hot sun of midsummer tends to desiccate their bodies; hence they take care to avoid it by staying well under cover.

Their enemies are many kinds of small snakes, as well as frogs, which snap at any slow-moving creature, and other carnivorous animals. Their size is too small to make them attractive to the larger reptiles and mammals, but their larvae no doubt serve as a tasty treat to their many smaller pursuers. On land the adults sometimes escape by suddenly jumping several inches. One does not associate the ability to leap with such short-legged and apparently earthbound creatures, but sometimes nature pulls little surprises on us. I remember how astounded a friend on the staff of the London Zoo was when she unpacked a shipment of salamanders I had sent her, and several of them went leaping off her table. They were the first she had received, she wrote me, and their habits were unknown to her. As this occurred before the days of transatlantic air post, it was something of a

Sardinian newt (*Euproctus platycephalus*). Othmar Stemmler



Western red-bellied newt (*Taricha rivularis*).  
Robert E. Lant: Annan Photo Features







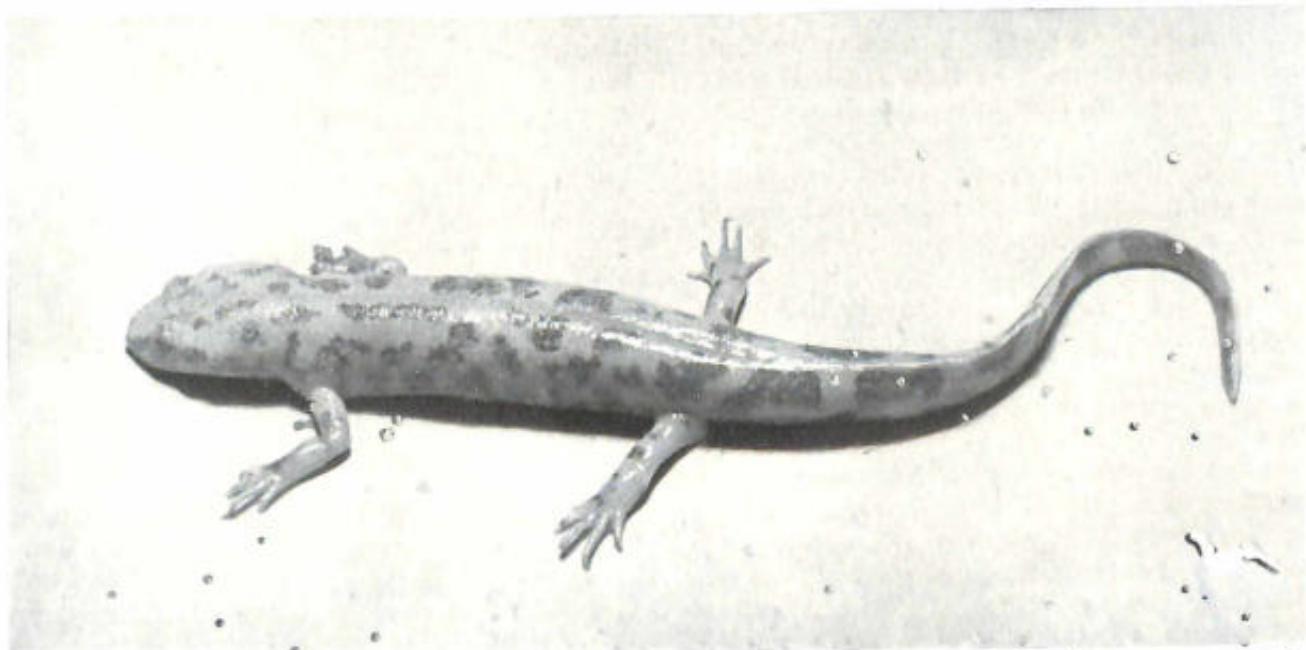
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Sardinian newt (*Euproctus platycephalus*). Othmar Stemmler



Western red-bellied newt (*Taricha rivularis*).  
Robert E. Lunt; Annan Photo Features





Eggs of red-backed salamander (*Plethodon cinereus*).  
Charles E. Mohr

feat to pack them so they would arrive healthy and lively at the end of a two- or three-weeks' boat trip.

The Ocoee salamander, *Desmognathus ocoee*, is one of the smaller members of the genus, as its size does not exceed 3 inches. It is found only in the Ocoee Gorge in southeastern Tennessee, living on the faces of rocky cliffs and hiding in the deep cracks between the rocks, which are always moist from concealed springs or from spray rising from mountain torrents at the foot of the gorge. No doubt a wealth of small insects also seeks such retirement and makes an excellent food source for these agile little salamanders.

The seal salamander, *Desmognathus monticola*, is a solidly built mountain dweller, reaching a maximum length of 5¾ inches. It lives in bogs at the bottom of ravines or along the banks of mountain brooks, by day retiring under stones and pieces of bark but at night coming to the entrance of its burrow. Its rounded nose and sleek, shining brown body suggest in appearance a tiny seal, so for many years it was known by the scientific name of *Desmognathus phoca* (*phoca* being the Latin word for "seal"); when it was discovered that the specific name of *monticola* had been published at an earlier date in describing the same creature, the later but more descriptive name *phoca* had to be abandoned. The seal salamander ranges through the hills and mountains from southwestern Pennsylvania to northern Georgia and Alabama.

The giant of this genus is *Desmognathus quadramaculatus* (Plate 14), the black-bellied salamander, which is known to attain a length of 7¾ inches. It is rather bold, too, for a salamander, since it sometimes comes out of hiding in bright daylight. It is plentiful in rocky streams, especially where the water is coldest near a waterfall or spring. It is a strong and agile swimmer, and if disturbed when hiding under a stone on land it rushes into the stream, where it usually evades capture by swimming away as fast as it can. It occurs in mountainous regions from southern West Virginia to northern Georgia.

A contrast in size is the pigmy salamander, *Desmognathus wrighti*, one of the smallest of the genus, not known to exceed 2 inches in length. Its bronze color blends well with the dead leaves and sticks on the woodland floor where it makes its home. It can climb up rough tree trunks for a short distance during its nocturnal hunting. It is found at altitudes of 3500 feet and more in the Great Smokies and other mountains in Virginia and North Carolina.

The shovel-nosed salamander, *Leurognathus marmoratus*, is exceedingly rare in collections. It has smaller eyes and a more wedge-shaped head than do its relatives of the genus *Desmognathus*. It is known from the uplands of Virginia, North Carolina, Tennessee, and Georgia. It grows to about 5½ inches in length, and lives in mountain brooks, hiding under the stones on the bottom. Its irregular gray, tan, and olive pattern makes it nearly invisible in its chosen habitat. Perhaps that fact, as well as its remoteness from highways, makes it among the most uncommon of salamanders in vivaria or museums.

The woodland salamanders, genus *Plethodon*, were the earliest known of this group, and hence gave the family its name. They are found in most forested areas of North America, emerging at night, or during rainy weather by day, to hunt their food. In dry, sunny periods they often aestivate in rocky crevices or in holes underground. Their food consists of smaller invertebrates such as earthworms, beetles, and ants. They lay clusters of eggs on dry land under logs, in patches of moss, or in similar protected spots. The larvae metamorphose completely before leaving the egg and do not enter the water as the young of the majority of salamanders do.

The red-backed salamander, *Plethodon cinereus* (Plate 10), is a resident in many old garden plots where tree stumps or moisture-conserving debris are to be found. It especially likes the punky inside of a rotting log, and on a dry day anyone who does a little experimental digging may turn up several from such a location. This salamander has an all-gray color phase,



and in this phase it is called the lead-backed salamander. The gray and the red-backed individuals occur in the same "litter" in nearly equal numbers in some regions; in other places the red-backed ones are more numerous; while in still different places the lead-backed phase predominates. Both the red-backed and lead-backed ones have mottled black-and-white bellies, giving a salt-and-pepper effect to the lower surfaces. In a few places in New England, a pure coral red-back occurs among populations with normal coloring. This creature is truly a living jewel, with its graceful slender body colored in various tints of coral to rose, its black beady eyes shining in contrast.

A colony of red-backs has lived for many years under a certain broad steppingstone in my garden. Sometimes on very wet days they wander through

the adjoining flower bed, looking for food. They are attractive and harmless creatures, and may do an infinitesimal amount of good to the garden by devouring small insect pests that are always present. This form does not exceed 5 inches in length, and the average size is considerably less than that.

The delightful name of zigzag salamander is applied to *Plethodon dorsalis* to describe the wavy red or yellowish dorsal stripe characterizing this animal. While it sometimes inhabits wooded areas, it is more often found in rock slides or at cave entrances from Indiana to Alabama. The zigzag salamander reaches a length of 3½ inches.

*Plethodon richmondi*, the ravine salamander, closely resembles the lead-colored phase of the common red-back, but it has a dark, plain ventral surface

Rough-skinned newt (*Taricha granulosa*). Jack Dermid





instead of the salt-and-pepper belly of the latter. Its record length is 5½ inches. We find it from central Pennsylvania to eastern Indiana, south to western Virginia and Kentucky.

Weller's salamander, *Plethodon welleri*, is small, growing only to 3½ inches as an adult. It also looks much like the lead-colored phase of the red-back, but has numerous gold or silver blotches on its black back, with a uniform black belly. It lives high on Grandfather Mountain in northwestern North Carolina, at 2500 to 5000 feet elevation. Tragedy followed the discovery of this salamander in 1931, for the young herpetologist who first found it fell to his death on the mountain shortly afterward.

The slimy salamander, *Plethodon glutinosus*, receives its name because of the glandular secretion given off by its skin when it is roughly handled. This secretion is not caustic to human skin but does cling like thick glue to whatever it touches, so perhaps it makes the animal less attractive as food to some of its

would-be enemies. A large adult may be 7¾ inches long. It is black, usually with a more or less heavy sprinkling of small white dots on top and with a dark, slate-colored belly and throat. It ranges from central New York to central Florida, westward to Missouri, Oklahoma, and Texas.

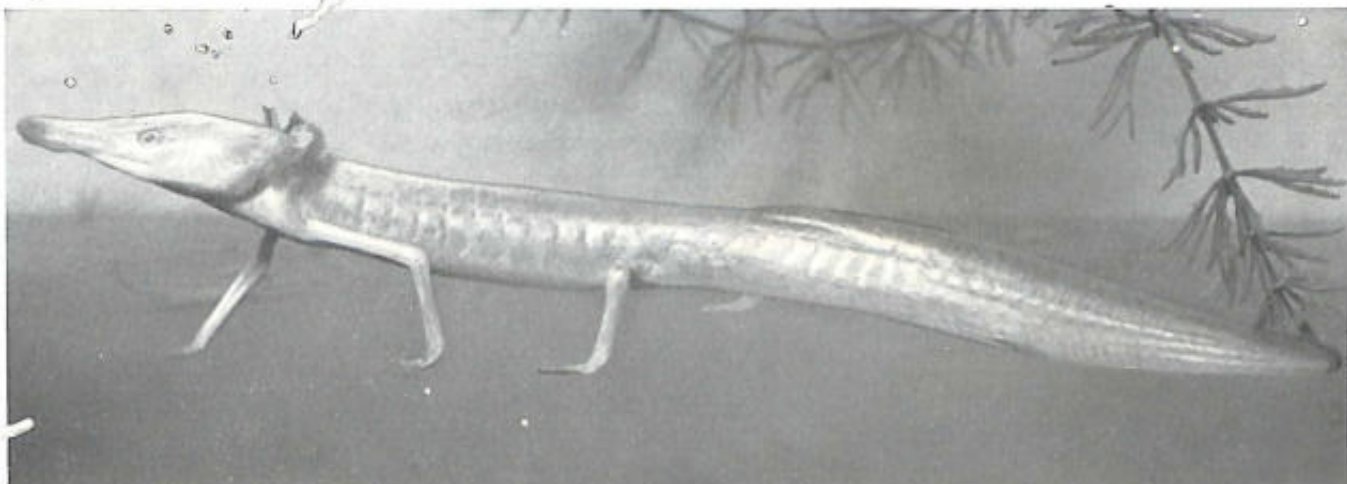
The red-cheeked salamander, *Plethodon jordani* (Plate 9), from the Great Smoky Mountains of North Carolina and Tennessee, has a mimic even in this remote habitat, one of the dusky salamanders also having red or yellowish cheek patches.

Several species of the genus *Plethodon* are found in the western United States. One of these is Dunn's salamander, *Plethodon dunni*, from coastal areas of Washington and Oregon. It frequents rock slides in ravines and may be found under mossy stones in permanent seepage areas near springs and small streams. When disturbed it takes to the water to hide under a rock in the stream bed. It grows to a length of slightly over 5 inches.

Slimy salamander (*Plethodon glutinosus*). Jack Dermid







Texas blind salamander (*Typhlomolge rathbuni*). Edward S. Ross

The four-toed salamander, *Hemidactylium scutatum* (Plate 17), is a 3½-inch creature that lacks a fifth toe. Its tail has a constriction at the base to enable it to be broken off easily if the salamander is pursued by an enemy. Other salamanders often lose tails in their struggle to escape, but this is the only one of the plethodonts to have the breaking point "made to order," as it is in many of the lizards. The four-toed salamander lives in sphagnum bogs or thick moss around woodland pools. The larvae are aquatic. The range is from Nova Scotia to Alabama and westward to Wisconsin, Missouri, and Arkansas, although its distribution in the South is discontinuous. This genus has only the one known species.

Another unispecific form is the many-lined salamander, *Stereochilus marginatus*, a slender brown or dull yellowish amphibian growing to 4½ inches in length and living on the bottom of swampy woodland streams along the coastal plain of southeastern Virginia and the Carolinas. It has a very small head and a short tail. Its common name comes from a series of narrow, dark, longitudinal lines on the sides, although these are not distinct in all individuals.

Some members of the Plethodontidae went underground many millions of years ago, and their descendants live in total darkness in subterranean rivers. Their color, when they are brought to the light of day by speleologists, is pale pinkish or white, and their bodies are so translucent that the outlines of the dark internal organs may be seen through the skin.

The grotto salamander, *Typhlotriton spelaeus*, reaches a length of 5½ inches and is blind as an adult, its dark eyes barely showing between the partially fused eyelids. As a larva it lives in mountain

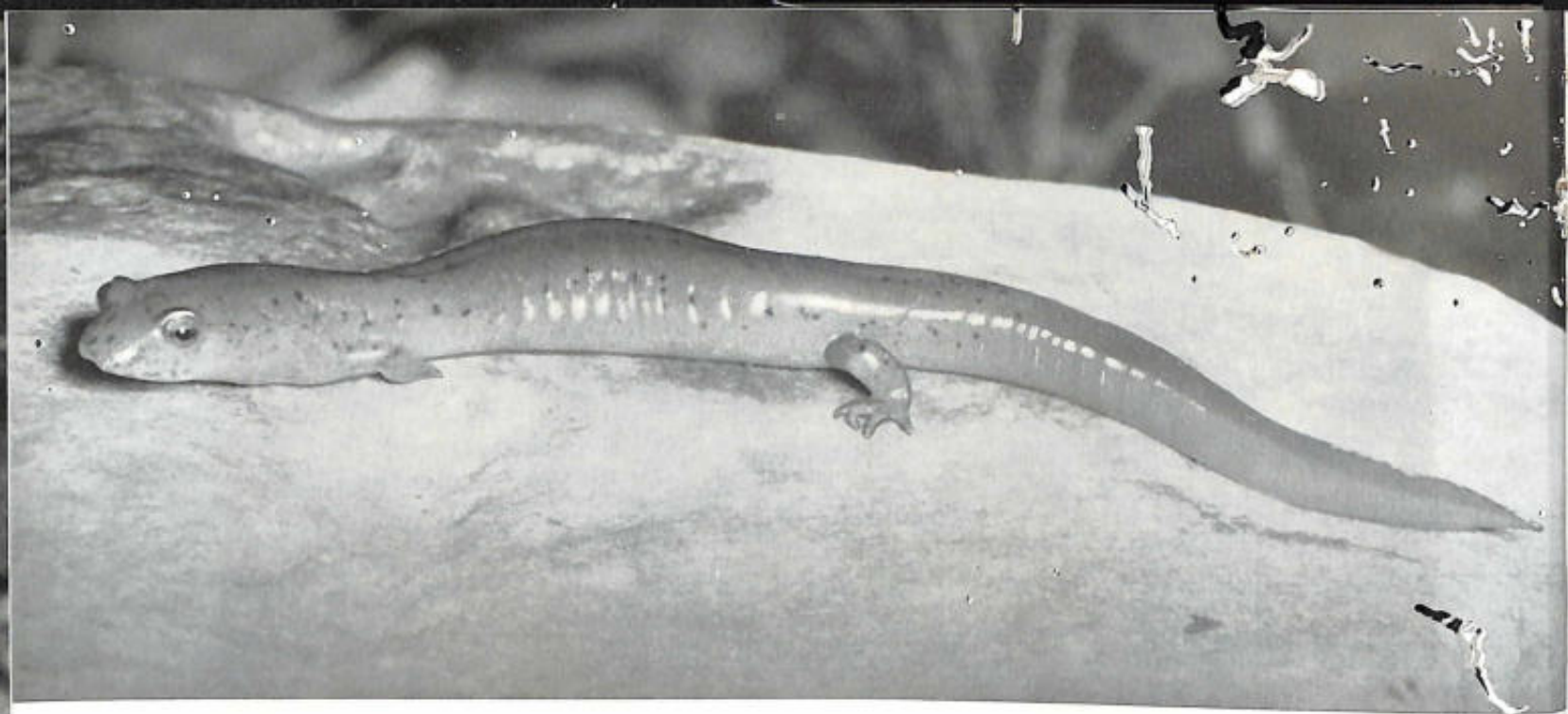
streams outside of the cave, and is dark-colored and has functional eyes like normal salamander larvae. But after metamorphosing the young adults find their way to a cave, the eyes ceasing to function in the total darkness and the lids growing nearly or entirely shut. The salamander never again leaves its cave home. Nothing is on record concerning its breeding habits. It is found in limestone regions of southwestern Missouri and in nearby areas.

The Texas blind salamander, *Typhlomolge rathbuni*, is an even more ghostly creature, as it has extremely slender legs, and it retains its gills throughout its entire life. The snout is peculiarly flattened and elongated, while the eyes are represented only by a pair of small dark spots under the skin. Its size is about 5¼ inches when fully grown. It occurs only in artesian wells and deep cave streams in the Balcones Escarpment, a rocky ledge separating the plateau of central Texas from the lowlands to the east.

The Georgia blind salamander, *Haideotriton wallacei*, was taken from a 200-foot-deep well at Albany, Georgia. It has very slender plumelike red gills, and the remainder of its 3-inch-long body is pinkish white with a slight iridescence. This animal was discovered only in the late 1930's, and it is interesting to speculate on what other weird creatures remain in these endless underground caverns.

The red salamander, *Pseudotriton ruber* (Plate 18), is a handsome red or orange creature, with irregular black spots on its back, growing to a length of over 7 inches. Its eyes are usually yellow. Old adults may become dull brown, as the dark spots seem to enlarge and run together. It is not uncommon around springs and in other cool, moist spots from





Spring salamander (*Gyrinophilus porphyriticus*). Karl H. Maslowski

Black salamander (*Aneides flavipunctatus*). Robert S. Simmons







Green salamander (*Aneides aeneus*). Karl H. Maslowski

southern New York to northern Alabama. It makes an attractive pet, as it has an inexhaustible appetite for small earthworms and will even take slivers of raw beef dangled on a straw in front of its nose.

A rather similar animal is the spring salamander, also called the purple salamander, *Gyrinophilus porphyriticus*, which lives in cold mountain brooks or forest seepage areas from Quebec to Alabama. It is considerably less common than the red salamander, however. A large adult may measure 8½ inches, and is attractively colored from salmon pink to reddish, with a light line running from the eye to the nostril.

The Carolina spring salamander, *Gyrinophilus dunni* (Plate 11), lives in the southern part of the

Blue Ridge Mountains into South Carolina, Georgia, and Alabama. It resembles the northern spring salamander but averages smaller in size, its maximum being only 6¾ inches.

The green salamander, *Aneides aeneus*, is also rarely encountered. Perhaps this is because it is a cliff dweller, living in small cracks in the face of the rocks in the Appalachian range from Ohio and Pennsylvania to Alabama. It is the only truly green salamander in the United States, and looks like a piece of lichen as it lurks among the rocks. It is also occasionally found in trees.

It has four western relatives in the Pacific area. One of these is the arboreal salamander, *Aneides lugubris* (Plate 16) which is the prize climber of the



family, having been found in a tree at a height of sixty feet in the nest of a red tree mouse. It is gregarious, as many as thirty-five individuals having been taken from a cavity in a coast live oak tree. It likewise lives at or below ground level, in stumps, decayed logs, rock walls, mine shafts, basements of houses, and rodent burrows, so it is very adaptable in its habits. It can squeak like a mouse by forcing air through the jaws or nostrils by contraction of the throat, and since most salamanders are voiceless and the family to which this one belongs has no lungs, the production of any sort of sound is rather remarkable. Another peculiarity of this salamander is that it breathes through its toes, having at the tips of the digits large blood sinuses which are believed to have assumed something of the function of external gills. It can change its color from a pale to a dark brown. In addition to the usual small invertebrate food, it is believed that the arboreal salamander may sometimes feed upon fungus growing inside the tree holes to which it climbs. It has large saber teeth in the lower jaw, which would seem useful in scraping or biting off fungi. This salamander bites to defend itself, too, and accounts of its ability to lacerate the skin of the human hand are on record. The female guards her eggs until they hatch, as do the other members of this genus.

The brook salamanders, genus *Eurycea*, are mostly aquatic in streams, ponds, springs, and other small bodies of water in which their special enemies, the fishes, do not occur in numbers. The two-lined salamander, *Eurycea bislineata*, is one of the commonest in eastern North America, from the St. Lawrence River to the Gulf of Mexico. It is a slender, delicate creature, not exceeding  $4\frac{1}{2}$  inches in length, with a wide golden stripe down the back bordered on each side by a dark line; but there is a good deal of variation among individuals, both as to the intensity of the dark lines and the general body color, which may be greenish, brown, or orange. I used to find many of them among the round white pebbles of the Powdermill Bogs north of Washington, D.C. The powder mills which stood there were the ones for which British soldiers were searching in the War of 1812, when they sailed up a branch of the Anacostia River almost to the huge bramble-and-pine thickets enclosing both the bogs and the powder mills. They never found the latter, and upon returning with mission unaccomplished, they burned the Capitol as a mark of their frustration. The bogs were fed by deep springs of cold water which trickled down through the stones, surrounded by rare woodland plants such as the swamp magnolia and the swamp azalea, and

carpeted by three kinds of insect-catching sundews—little plants with double spiky leaves having a sticky sap that lures flies and ants. When the insects are thoroughly mired in the trap, the leaves close around them and they are soon digested by the plant. Young salamanders are too large to be trapped thus, but they do have formidable enemies in the small crayfish which live beneath the stones and are always hungry.

Two-lined salamanders are not difficult to catch. A large wire tea strainer poked beneath the clumps of marsh grass may often bring out several, while the larvae come into a fine-meshed net if you hold it downstream while you raise some of the stones and other debris at the point where a spring overflows and becomes a miniature stream. There are usually abundant copepods, mayfly larvae, and other soft insects in such a spot, all of which serve as nourishing food for young and adult salamanders. In very wet weather, the adult may leave the water for a walk in nearby woodlands, where it probably finds a change in diet in the small slugs and earthworms that are abroad at such times.

The long-tailed salamander, *Eurycea longicauda* (Plate 13), grows to slightly over 7 inches in length, about three-fifths of this being composed of the tail, which is yellow with conspicuous black markings. It is less aquatic than the two-lined, being found by day hiding under fallen logs and stones and often in the mouths of caves. It ranges from New York to Alabama and Kentucky.

The three-lined salamander, *Eurycea guttolineata*, is closely related to the long-tailed salamander and occupies part of the same range, being found from Virginia to Florida and west to the Mississippi. Its record length is  $7\frac{1}{8}$  inches. It is a slender and graceful creature, and lives well in captivity on a diet of very small earthworms and soft-bodied insects.

The cave salamander, *Eurycea lucifuga*, has gone underground for its preferred habitat. It usually lives in limestone formations, from Virginia to Oklahoma, at the entrance to caves, where the light is weak. It climbs freely about on the rocky ledges, using its long, prehensile tail, or sometimes hanging entirely by the tail.

The genus *Mamiglus* is distinguished by having only four toes on the hind foot. The single known species is the dwarf salamander, *Mamiglus quadridigitatus*, growing to a maximum length of  $3\frac{3}{16}$  inches. It lives in coastal plain regions from North Carolina to Florida and westward to Texas.

Along the Pacific coast lives a slender, elongate genus of salamander that is named *Batrachoseps*.







The California slender salamander, *B. attenuatus*, rests under fallen logs, its body curled into a tight, springlike coil, like a tiny snake, with its head pointing toward the center of the coil. Its minute limbs are not of much use in walking; hence it employs a sinuous movement of its body to get over the ground. It often stays in abandoned burrows of other animals, as it cannot make its own burrow if the soil is firm and tightly packed. It is gregarious, a dozen or more sometimes being discovered under the same piece of shale. Egg-laying coincides with the arrival of the rains, which usually begin in October, while hatching commonly occurs in the spring. A single female is supposed to produce not more than twenty-one eggs in a season, but when several females lay in the same spot, a much larger number of eggs often occurs. Adults may remain near their eggs but are not known actually to brood them.

*Batrachoseps wrighti*, the Oregon slender salamander, is known from Linn and Clackamas counties, Oregon. It hides under chips and logs in forests, and often assumes a coiled attitude somewhat like that of a resting snake.

The genus *Hydromantes* is known from California and southern Europe, a strange distribution indeed. Furthermore, the three European forms are the only members of the family Plethodontidae occurring in the Old World. *Hydromantes italicus* lives in southern France and northern Italy in mountain caves, where it climbs at night with great agility over the face of the rock in its search for small scorpions

and beetles. The tongue can be protruded for over an inch, and as the salamander is rather slow in its body movements, its food-getting is considerably improved by the quickly extensible and probably sticky tongue. *Hydromantes genei* lives on the island of Sardinia, under stones and in shady places. A third form, *Hydromantes gormani* (Plate 15) from caves of Tuscany, was recently described. It seems to have the same habits as the species already known, but differs somewhat in color pattern and bodily proportions. They all grow to a length of approximately 4¼ inches.

Their California relative, *Hydromantes platycephalus*, lives in rock slides, usually on wet earth but seldom in water. It is nocturnal as a rule but sometimes emerges by day. The webs between the toes give its feet a good hold on slippery rocks when it is walking. The short, heavy tail is almost a walking stick. When the salamander goes downhill, the tail tip is curled to point in that direction and is braced to act as a brake.

In going uphill, the tail swings first right and then left, bracing alternately as each hind foot takes a step. Although this salamander is not a rapid walker, it also can catch moving insects by extruding its mushroom-shaped tongue for half its body length in order to seize its prey. Its food consists of centipedes, spiders, termites, beetles, and flies. Not much is known about details of its reproduction, and it is suspected that the female is viviparous.

*Hydromantes shastae*, the Shasta hydromantes, is

Large-blotched salamander (*Ensatina klauberi*). R. Van Nostrand: San Diego Zoo







Monterey salamander (*Ensatina eschscholtzii*). R. Van Nostrand: San Diego Zoo

a newcomer to the world of science, having been described in 1953. It is a cave dweller, living not very far from the entrances of several limestone caves in Shasta County, California. It is more sluggish than the Yosemite *Hydromantes platycephalus* and cannot stand so much cold, becoming torpid at 3 to 4°C, a temperature at which *platycephalus* continues its usual activities. The blunt tip of the tail is used in walking and climbing, as it also is in the related species.

The yellow-blotched salamander, *Ensatina croceator* (Plate 12), is known from Kern County, California, and nearby localities. As in other members of its genus, the adult color pattern is paler and less definite than in young individuals. An adult when molested stands high on its toe tips, sometimes rocking back and forth on stiff legs, its body curved downward and its tail arched and swinging. A milky, astringent fluid is secreted by the tail in moments of danger, and sometimes the salamander squeaks by forcing air through the nostrils or lips by a contraction of the throat.

The yellow-eyed salamander, *Ensatina xanthoptica*, occurs in the coastal range of California. The male goes through an elaborate courtship ritual, rubbing the female's neck and head with his nose, inducing her to follow him and finally to pick up with her cloaca the spermatophore he has just deposited, while he strokes her back with his tail.

A good many salamanders of this family occur in the United States and tropical America, but much still remains to be learned concerning their habits and life histories.

## The Mudpuppies and the Olm

(Family Proteidae)

According to the old fisherman, "That critter took the bait and then hung himself on the hook." The bait-stealer often turns out to be a mudpuppy or water dog, one of the eight forms of the genus *Necturus*, found from southern Canada to the Gulf of Mexico and from New Jersey to the Mississippi basin.

All are neotenuous—that is, they are perennially larval in form, as they never lose their gills, and they breed without ever attaining a truly adult stage. The gills are very conspicuous, forming a heavy cluster of dark red "plumes" at the sides of the neck. The body color is usually gray to rusty brown, with scattered, often indistinct bluish black spots above. There are only four toes and fingers on the feet and hands, but these are nearly as well developed as they ever are in any normally aquatic tetrapod.

While most salamanders are voiceless or at most emit only a feeble squeak or grunt, popular superstition falsely attributes the ability to bark to these animals; hence their popular names.

They lead a rather secretive life in weedy streams and rivers, taking any small-sized aquatic food they can find, from snails and insect larvae to crayfish, fish and frog eggs, and even little fish.

The mating season comes in autumn, and at this time both sexes often share the same sheltered hollow in a stream bank. In spring the female lays her eggs and stays with them until they hatch, or some-





Eggs of mudpuppy (*Necturus maculosus*).  
Charles E. Mohr

times longer. The eggs are small, light yellow globes, and are attached singly to the underside of a submerged rock or log. They hatch in from thirty-eight to sixty-three days, depending on the water temperature. The young when hatched are a little less than an inch long. They are mature enough to breed when they have reached a length of 8 inches at an age of about five years.

The mudpuppy, *Necturus maculosus*, is found in permanent ponds and lakes from southern Canada to the drainage of the Tennessee and Missouri rivers. It is nocturnal as a rule, but in muddy or weed-grown waters it also hunts by day for small fish and their eggs, snails, aquatic insects, and similar food. The size of its gills indicates the condition of its water habitat: if the water is cold and fairly fresh, its gills are small and contracted, but if the water is warmer and more stagnant, therefore having less oxygen, the gills become large and bushy, moving constantly in order to pick up all the oxygen that they can possibly obtain.

The only close relative of *Necturus* is the olm, *Proteus anguinus* (Plate 19), which lives in a permanently larval form in the lightless depths of the caverns of Carniola, Carinthia, and Dalmatia, in southern Europe.

The olm grows to a length of about a foot, and is white, being a dweller in total darkness. Its three pairs of gills are a beautiful carmine red, however. While it has fairly large and strong limbs for a purely aquatic animal, it has only three fingers and two toes. The eyes are hidden under the thick opaque skin, which is nevertheless very susceptible to light, turning eventually to solid black when the animal is kept for several months in a normally lighted laboratory. Olms live very well in captivity if their water is kept fresh and at a constant temperature of around 50°F., since they are able to sense the presence of small worms or crustaceans introduced into their tank, finding and seizing their food without difficulty. They can also fast for long periods without any apparent harm.

In a tank containing several *Proteus*, some eggs were found fastened singly to the undersides of stones. They hatched in ninety days, the larvae being  $\frac{7}{8}$  inch long and resembling the adults closely except that their eyes were still visible, while the fin, limited to the tail in adults, extended partway along the body. Occasionally the female *Proteus* does not lay the eggs but keeps them in her oviducts until the young are ready to be born alive as little replicas of their parents—a phenomenon quite rare among salamanders.

As we have noted elsewhere, neoteny may be due to some factor which prevents the release of the thyroid hormone into the circulation. Cold apparently inhibits the release of this hormone, for some high-altitude salamander larvae fail to metamorphose although the species does so at lower levels—as does the tiger salamander, *Ambystoma tigrinum*, the "axolotl" of the Rocky Mountains. Some other axolotls live in warmer waters but remain larvae for long periods, due probably to some inherited defect in the mechanism for dispersing the thyroid hormone. Other factors, such as a lack of vitamins, an overabundance of calcium, and various internal conditions, also tend to inhibit metamorphosis.

## The Sirens (Family Sirenidae)

The names of Greek gods and heroes have often been taken over by modern zoologists as scientific names for animals. For instance, among the salamanders we have *Triton* and *Oedipus* (there was even a species named *Oedipus rex*)—not the least interesting being the genus *Siren*, named after the



beautiful charmers who sang sweetly to Ulysses from offshore rocks.

Our amphibian sirens do not sing, except to produce a faint yelping or whistling sound, nor are they particularly beautiful except in the eyes of a herpetologist. They do, however, live in water, and they often hide among the rocks at the bottom of a shallow stream or ditch. They are quite eel-like in appearance, since their hind legs have disappeared and their forelegs are rather small and not conspicuous. They move with strong undulations of the body as they swim among the water weeds on their nightly hunt for worms, small snails, shrimp, and occasionally filamentous algae. They burrow into a thick mass of weeds for concealment. Sometimes they come out on the shore of a pond, and they can even wriggle over the small dams that may stand in their way.

They breathe by means of external gills, which are bunched together on the sides of the neck. These gills are occasionally reduced in size and sometimes do not function at all. If conditions in their native pond are not suitable, the gills of the larvae grow smaller until they are mere stumps. This is not a true metamorphosis, for *Siren lacertina* never metamorphoses,

even with the artificial stimulation of powerful drugs, but remains entirely neotenic for its whole life.

Another peculiarity of *Siren* is the complete absence of the pelvis. This condition is also found in the caecilians, the first order of living Amphibia, as well as in some members of the fossil order Lepospondyli, known from the Carboniferous and Permian periods. Most other legless amphibians still have a remnant of a pelvis, an evidence of their descent from the typical ancestral form, which had a full complement of limbs.

In creatures like sirens, with a disproportionately long body and rather narrow girth, the capacity of the heart needs to be increased. This is done by certain bulbous or finger-like extensions of the auricles, which greatly increase their volume. The ribs are many fewer than in most vertebrates, occurring only on the anterior vertebrae.

The skin secretion of *Siren* is quite innocuous. This fact also is rather unusual among the salamanders, where the poison-secreting glands of the skin usually give the animal the protection from its enemies which its bodily structure and its inability to run away quickly may not insure to it.

Mudpuppy (*Necturus maculosus*). Lorus and Margery Milne





The rate of growth in sirens appears to be rather slow. A ten-year-old individual had reached a length of about 20 inches. A captive specimen has been known to live for twenty-five years.

*Siren lacertina*, known as the great siren, is found from Maryland south to Florida and Alabama. The lesser siren, *Siren intermedia*, occurs as far west and south as Tamaulipas, Mexico.

The only other member of this family is *Pseudobranchius striatus* (Plate 20), the mud siren, occurring from South Carolina through Florida. The Florida variety may reach a length of 8¼ inches. Nothing is known of its mating habits. Eggs are deposited singly or in groups attached to water plants. The adults apparently spend their lives in cypress swamps, bogs, and marshes, where they burrow in mud or hide among the submerged vegetation. Their general

dull brown, gray, or greenish color makes them next to invisible among the water plants, but collectors can usually secure a good number of them by rolling masses of submerged weeds onto the bank and picking up the mud sirens as they try to scramble back into the water.

When ponds dry up due to prolonged drought, both *Siren* and *Pseudobranchius* have been found encased in little tunnels of dried mud, just the size of the animal's body and as much as twelve inches below the former pond bottom. At this degree of desiccation the skin is no longer slimy to the touch, while the gills have been greatly reduced in size. After adequate water is again available, the gills may return to their normal size in a week. Experiments have proved that sirens are able to survive at least two months of this total dryness.

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### PART THREE

# The Frogs and Toads and Their Relatives (Order Salientia)

THIS group of the Amphibia, comprising toads, frogs, and their relatives, is much the largest of the three living orders. There are some 2600 species belonging to about 245 genera known today, and these extend through all temperate and tropical lands except perpetually snow-capped mountain tops, waterless deserts, and some islands of the Pacific. The permanent freezing of the arctic and antarctic regions prevents their occurrence there, although some kinds live in the unfriendly climate of Patagonia, while others survive within the Arctic Circle in Europe.

In order to classify these diverse creatures properly and to discover their true relationships with one another, scientists have studied their body structure as well as their life-history patterns, and have been able thus to mark off some very well-defined groups. While there has been much argument as to just which of the structural characteristics were the least adaptive to changing habits and environments, and hence most likely to have perpetuated the original characteristics as they arose in the very earliest amphibians, zoologists are now pretty well agreed that the verte-



brae and ribs show more stability in this respect than any other parts of the skeleton.

Living frogs are thus grouped into five suborders under the order Salientia, as follows:

I. Amphicoela, the most primitive group, having the centra of each vertebra biconcave—Leiopelmidae.

II. Opisthocoela, having the anterior centrum flat or concave, the posterior one convex; ribs present—Discoglossidae, Pipidae.

III. Anomocoela, having the anterior centrum concave, the posterior usually convex; the sacral vertebrae fused to the coccyx; no ribs present—Pelobatidae.

IV. Procoela, having the anterior centrum concave and the posterior usually convex, as in the Anomocoela, but with the sacral vertebrae free—Bufonidae, Atelopodidae, Dendrobatidae, Rhinodermatidae, Hyliidae, Heleophrynidae, Rhinophrynidae, Leptodactylidae, Pseudidae, Centrolenidae.

V. Diplasiocoela, having the first seven vertebrae procoelous, the eighth biconcave—Ranidae, Rhacophoridae, Microhylidae, Phrynomeridae.

Students of zoology agree that four families of the Amphibia are more primitive than the others: these are the Leiopelmidae, the Discoglossidae, the Pipidae, and the Pelobatidae, all of these belonging to the first three of the suborders given above. They display many characteristics that seem to separate them from the more highly developed frogs of the remaining fourteen living families, which we consider to have been evolved at a much later date.

The ancestors of our present-day frogs and toads were the first vertebrates to become adapted—at least in most of their species—to a predominantly terrestrial existence. They have never wholly succeeded in breaking the chain that binds them to an aquatic life, such as the next lower order, the fishes, must still lead, as anurans usually must insure their larvae of reaching water in which they may undergo metamorphic changes before finally and permanently emerging onto land as young adults.

Their life history has, therefore, been of prime importance to this group in its evolution from essentially aquatic forebears through some 300,000,000 years to its present numerous and diverse representatives, most of which are land dwellers for at least the greater part of their lives. Great variety is apparent in the methods that the anurans came to use in changing over from a life in water to a life for the most part terrestrial. Some details of the reproductive process are consequently given for each of the following families that comprise the living Salientia.

## The Leiopelmids

(Family Leiopelmidae)

This family displays primitive structural characteristics and a life history that place it among the most ancient stocks of frogs of which we have record. Only two genera are known, one of these from New Zealand, the other from the northwestern United States and southwestern Canada. Both possess two tail-wagging muscles, although neither has a tail. Both have all of the vertebrae amphicoelous—that is, the anterior and posterior surfaces of the centrum of each vertebra are concave and are thus unlike those of any other living frogs.

The New Zealand genus, *Leiopelma*, is known from three species, which are among the few amphibians to be found on that island. They are all small in size, none exceeding 2 inches in length. They live near mountain tops where the air is always moist and cool. As there is little standing water on the precipitous slopes, the eggs of Archey's frog, *Leiopelma archeyi*, are deposited under stones or logs, the larvae developing completely within them. After hatching, the young frogs require no surface water, but move about freely on the damp earth and vegetation. They still retain their tails at the time of hatching, but have absorbed them in about four weeks.

The eggs of Hochstetter's frog, *Leiopelma hochstetteri*, were found during the months of November and December in the seepage from a spring on a mountain slope. Near the watercourse adult frogs were sitting in the slowly moving water in holes or tunnels in the extremely wet clay. These tunnels were probably made by large dragonfly nymphs, and the frogs had taken over these excavations for a foot or more underground. Groups of two to eight eggs lay on the saturated floors of the tunnels, resting partly in the water. Adult frogs lingered near the eggs but were not sitting on them. The eggs were attached end to end to form a beadlike string, each egg being about  $\frac{3}{16}$  inch in diameter when first laid and about  $\frac{3}{8}$  inch when ready to hatch. Eggs from each of the two ovaries are laid separately, and the ovaries contain both large and small eggs at all times of the year, hence the maturation period seems to be long. It is usually the male that sits near the eggs to guard them. Not all eggs hatch at the same time; those in large clusters often take several days to hatch. Often one or more eggs in a cluster fail to show any sign of development. About forty-one days after being laid, the first of the young froglets appears, while the last





Surinam toad (*Pipa pipa*), in amplexus and (at right) female with eggs embedded in skin. Raymond J. Cummins

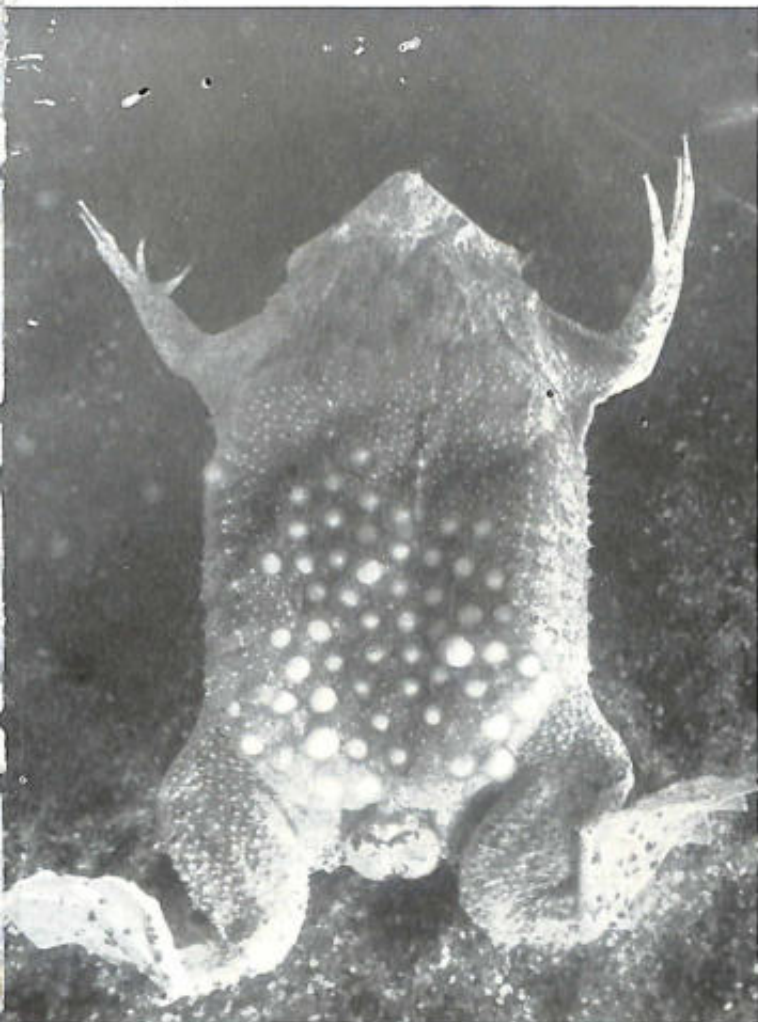
of the same cluster may not emerge until nine days later. Just before hatching, the embryo measures about  $\frac{3}{4}$  inch in length. The egg yolk serves to nourish the froglet as long as a month after it has hatched.

The long tail of the developing froglet is used in breaking out of the egg capsule. This is a rather lengthy process, but it is at last attained by the vigorous movements of the tail, which finally rupture the walls of the capsule. Sometimes the hatching frog remains for a while with its tail projecting from one end of the gelatinous mass and its head from the other end. The tail is not only muscular but vascular as well. Cutaneous respiration occurs by means of blood vessels across the abdominal wall and tail of the embryo. The lungs are not sufficiently developed to be used as breathing organs until some weeks after hatching; hence respiration through the skin supplies oxygen to the froglet until its lungs can function.

Half a world away, in swift, icy streams of mountains in the Pacific Northwest, lives the only other known representative of this family. It is *Ascaphus truei* (Plate 21), the tailed frog—the only criticism of the popular name being that this amphibian does not have a tail! The odd-looking appendage at the end of the male's body is really an exterior cloaca, which is used at breeding time to introduce the sperm directly into the female's body. No other frog has this specialized type of fertilization.

Another peculiarity of tailed frogs is that they are voiceless, since the male does not have to attract a distant female to the breeding ground by his call. In fact, he could not be heard above the roar of rushing water in his native mountain streams even if he had a voice. Instead, at breeding time he creeps about on the bottom of the stream until he has found a female. Her eggs are deposited in strings attached to the





lower surface of submerged rocks. The breeding season is rather long, freshly laid *Ascapbus* eggs having been found from May to September. The clutch contains between twenty-eight and fifty eggs, each about  $\frac{1}{3}$  inch in diameter. They hatch in about a month. In the first hour of larval life, a triangular adhesive organ on the head becomes apparent; the tadpole attaches itself by this organ to a rock to keep from being swept downstream by the swift current. The tadpole can even climb a short distance out of the water on wet, projecting rocks by using the suction of its mouth, probably finding algae and other microscopic food there. A metamorphosing froglet with the tail still unabsorbed was found inland more than a hundred feet from the nearest water after a heavy rain, indicating how active it can be at this stage.

The nostrils of the tailed frog embryo are unique among amphibians in being produced into irregular

funnels that can bend downward and close when a stream of water is turned on them. Their closing controls the amount of water passing through them and out through the median spiraculum, or breathing pore. No other tadpole is so equipped. Even small food particles can be ingested through the external nostrils. The usual method of mouth feeding is also followed, since the tadpole scrapes algae off the rocks as it moves along while maintaining its grip by the sucker on its head. It usually metamorphoses between July and September of the year after hatching.

The adult tailed frog can, and indeed must, endure a colder temperature than most other frogs demand, and hence it frequents only clear, shallow, cold streams in well-forested areas where the water remains below 40°F, even on a summer's day. To be kept alive, captive specimens must be placed in melting ice or stored in a refrigerator. In dry seasons they are always to be found in water, but with the coming of rain they may stay on the shores of a stream as long as the rain lasts. Their food consists of small spiders, beetles, isopods, and insect larvae. Usually they are solitary when on land, but occasionally two or three are encountered in an especially good hiding place.

## The Tongueless Frogs

(Family Pipidae)

Examples of one of the strangest of amphibian families, the Pipidae, are found in South America and in Africa. They are without tongues and hence are often alluded to as the Aglossa, or tongueless frogs. They live almost entirely in the water and get their living practically as scavengers, for they sweep the mud with their long, slender fingers and seize upon any small animal, dead or alive, that may be fanned up to their eager mouths.

The most familiar of the South American forms is the Surinam toad, *Pipa pipa* (Plate 22). It is shaped like a squarish pancake—a somewhat scorched pancake at that, as its color is a uniform blackish brown that renders the animal virtually invisible against the black mud of the Amazon or the Orinoco, where it makes its home. Its head is flat on top but has peculiar flaps of skin on the jaws, which disguise its outline well. Its nose is pointed, and its tiny, lidless, black eyes look like minute beads. Most land-dwelling frogs have very large and handsome eyes that project in a hemisphere above the skull, hence they can literally look behind them without moving.



This they need to do in order to escape from their ever watching enemies. Some aquatic frogs have bulbous eyes that project partly above the water as their owners float on the surface, giving them a good view of the dangers that lurk in both air and water. Although the Surinam toad has rather small eyes in comparison with these, it can spy an enemy about to strike from above, from below, or from any other direction, as its ability to keep watch for danger is the price of its very survival.

The fingers of the Surinam toad are long and flexible, the tip of each one having a star-shaped cluster of glandular filaments that add greatly to the tactile properties of the hands, so that even in thick mud, or at flood time when the river water is opaque with brown silt, the animal can find its food. Its hind legs are slender, and their toes are also flexible, and webbed for a powerful swimmer's kick. The wide, flabby body has no "waist line" and out of water seems awkward in the extreme, but in water it bends and undulates with the creature's motions and is seen to offer very little resistance to the frog's progress.

Surinam toads live quite well in captivity, but their remarkable breeding habits are not often seen in an

aquarium tank. We who are associated with the National Zoological Park in Washington, D.C. were pleased, therefore, when a pair of captive Surinam toads began mating activities there. The male first uttered a series of metallic, clicking calls, then encircled the body of the female with his arms, pressing her extended oviduct over her back and beneath his body, thus apparently helping in the extrusion of the eggs. As each egg appeared, the male maneuvered it onto the thickened skin of the female's back. After some sixty eggs had been placed in this manner, the female's quota was attained, for no more eggs were laid. Now the male retreated, and the female remained quiet for several hours while the skin of her back slowly swelled to enclose and cover the eggs deposited there, each one of them having its own little pocket. After this, she looked ridiculously fat on top but it did not seem to hamper her movements in the least, for she soon went unconcernedly about the business of searching the bottom of the tank for stray bits of chopped beef—the zoo's best equivalent for her natural food. Incubation of the eggs on her back proceeded normally, and one morning a "lid" in the skin of her back popped up and a tiny Surinam toad-

Clawed frog (*Xenopus laevis*). G. F. de Witte: Institut des Parcs Nationaux du Congo Belge







Clawed frog (*Xenopus laevis*). Wilhelm Hoppe

let wriggled free and went swimming to the top of the aquarium. He had no gills or tail, since these typical larval appurtenances had been developed and then reabsorbed during his long wait to be "born" in the cyst on his mother's back. Some of his brothers and sisters soon emerged, and by the next morning they were all out—fifty-five of them—and now the water was thick with tiny black forms looking like bits of last year's dead leaves floating in the water. Most of them thrived and grew under the watchful care of the zoo keeper—their mother had been removed to another tank after her young had hatched, for fear she would begin to eat them in the absent-minded way that marks most amphibian parents. Soon the young toads were nearly half the length of their parents. While a few died, most remained vigorous and in good health. The efficiency of this method of caring for the young was indeed thus demonstrated.

A dwarf toad, *Pipa parva*, lives in Venezuela and the Guianas. It measures less than 2 inches in length, compared to the 8-inch maximum of the Surinam toad. A third form, *Pipa snethlageae*, occurs in Pará on the Amazon. Their habits are apparently very similar to those of the Surinam toad.

Another South American genus is *Protopipa*, known from Pernambuco, Brazil. Aside from having teeth on the maxillary bone, which *Pipa* lacks, it is not dissimilar to the latter genus.

In Africa live three other genera of this curious family. Members of the genus *Xenopus* are usually called clawed frogs, because their three inner toes are equipped with little black curved claws, resembling birds' claws in miniature. These may be useful in digging in the mud for insects, for the African pipids are aquatic too, although a bit less helpless on land than are their American cousins. *Xenopus* does not incubate its eggs as *Pipa* does, but deposits them in still water.

*Xenopus* really has a unique claim to fame, however, for it was on unfertilized females of this genus that the first reliable test for pregnancy in the human female was perfected. About twenty years ago, doctors in South Africa injected urine from pregnant women into the bodies of young unmated female clawed frogs. In a few hours the frogs began to lay eggs, the laying having been stimulated by certain hormones present in the urine of the pregnant women. The injection of urine from a woman who was not pregnant had no such effect on the frog, and no tendency to lay eggs was aroused. At first the demand for African clawed frogs by gynecologists all over the world was tremendous, but soon it was discovered that female frogs of almost every kind could be used in these tests for human pregnancy.

Clawed frogs may live quite well in captivity. I kept three for several years in my laboratory. Each



time I came near their tank, they rose expectantly to the top, hoping for food. When I handed them a small earthworm or a cockroach, they leaped out of the water and nearly swallowed my finger tip in their eagerness; but their soft little mouths did no damage. Sometimes they gave a faint chirping call, and once I observed some attempts at mating, but they laid no eggs.

In its native haunts in South Africa *Xenopus laevis* is called the platanna. A large female measures over 5 inches in length. With its projecting, upward-looking eyes, smooth skin, streamlined body, and heavily muscled legs ending in broadly webbed toes, the frog seems well adapted to its aquatic existence.

It is the three inner toes of the platanna's hind foot that bear the short black claws. These are probably used to rake up the mud, not only in locating food but also to render the water turgid when the platanna dives to the bottom to escape a sudden danger. If you put the platanna on land, it can move only slowly, in a series of awkward, flopping jerks; but in the water it progresses with the strength and certainty of a small submarine. It is as skillful at swimming as any fish.

In feeding, the platanna uses its long, slender fingers to "fan" its food into its mouth. Or it will pick up a worm in its fingers and convey it to the mouth with considerable speed. Its appetite is almost impossible to satisfy, for it will eat almost any kind of animal matter, including carrion if it is in small enough fragments to be swallowed. Even its own tadpoles and young are not safe from its tremendous appetite, be-

cause it sees in a moving object only a possible food source and does not have the intelligence to recognize its own offspring. Small fish, fresh-water crustaceans, and aquatic insects and their larvae are also eagerly accepted. A captive platanna soon learns to take slivers of raw beef or small worms from its captor's fingers. The frog apparently has some faculty of memory, for if you feed it regularly at the same corner of the aquarium, it will soon wait for you there at the approach of its usual feeding time.

The platanna can move backward in the water or on land by a muscular forward movement of the hind legs. This reverse direction must certainly be of value to it in escaping from predatory fish, birds, crocodiles, and water turtles that would like to make a meal of it.

At molting time in an aquarium a captive platanna has to go through some very strenuous contortions to shed its tight and outgrown skin. In its native pool, it may without much effort brush it off among the stems of reeds. Probably its hind claws are also of assistance in this disrobing.

The ability to change color in a limited degree to match the surroundings is well developed in the platanna. When the aquarium is covered with black paper, the animal turns nearly black in a short time. If the cover is white paper, the skin shortly becomes a pasty buff; and if it is spotted paper, the frog assumes a mottled appearance.

In South Africa, where the platanna is found wild, its "home" rivers usually dry up in summer. In exceptional cases some of the frogs migrate short distances

Clawed frog (*Xenopus laevis*), mating. Wilhelm Hoppe





overland to more permanent bodies of water if there are any, but usually they have to go underground by burrowing into the cool, damp soil, where they remain in a state called aestivation until the winter rains cause them to begin feeding and mating again. During their summer of enforced inactivity they do not feed at all, and their metabolism is greatly lowered during this period. While they get quite thin during their long fast, they put on weight rapidly as soon as the rains bring out an abundance of food. They devour countless mosquito eggs and larvae, and hence are of great importance to man in the control of malaria and other mosquito-transmitted diseases over the entire region in which they occur.

At the coming of the rains the platannas mate and deposit their eggs on the submerged stems of aquatic plants. The eggs hatch in about a week, and the young larvae remain motionless at the surface for another week. They have no mouths at this stage, being still nourished by the remnants of the egg yolk. Then they commence to swim around, finally congregating head down in rather deep water. Unlike most tadpoles, they do not scrape or nibble at the algae after their mouths appear. Instead they suck into their wide, soft mouths the minute protozoans found in the algal masses, keeping the highly nutritious protozoan food and expelling the excess water through slits on the sides of the head. Below the tadpole's eye is a long, slender tentacle which seems to be tactile in function. The adults have the tentacle, but it is much reduced in size.

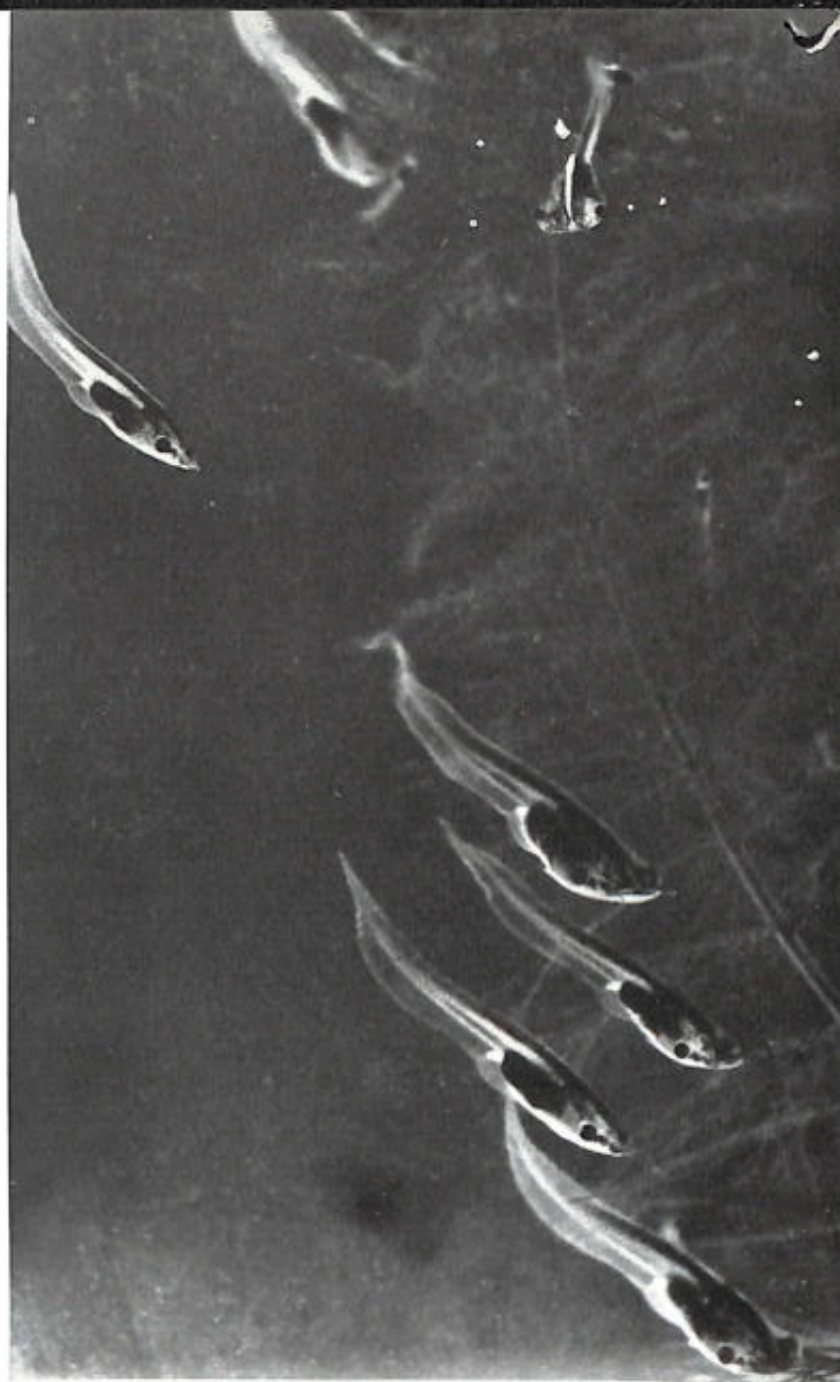
*Hymenochirus*, known by three or four species from the rain forest of the Congo, seems to be intermediate in structure between *Xenopus* and *Pipa*. It has the three inner toes equipped with claws, as in *Xenopus*, while some of its skull characters resemble those of *Pipa*.

*Pseudhymenochirus*, from north of the Congo, is so imperfectly known that nothing about its life history is on record.

## The Fire-Bellies and Midwives

(Family *Discoglossidae*)

Frogs of this Old World family are characterized among other things by a round, disklike tongue which adheres by nearly all of its base to the floor of the mouth, so that it cannot be extended when its owner takes food. There are not many living genera belong-



Larvae of clawed frog (*Xenopus laevis*). Wilhelm Hoppe

ing to this family, but they have a very wide distribution, *Barbourula* being found in the Philippines, *Bombina* in Europe and Asia, *Alytes* in Europe, and *Discoglossus* in Europe and northern Africa.

The fire-bellied toad, *Bombina bombina*, or "Unke" as the Germans call him, is a dull gray frog when you see him floating among the lily pads in a quiet pond. But just startle him and his appearance changes completely. He throws his head back, arches his body, and brings into prominence the fiery orange spots on his lower surface. Even his arms and legs are stiffened and held so that their under covering of orange skin is equally prominent. The little frog remains motionless with these warning colors on display until



the predator, who was searching for something quite different in appearance, is satisfied that this is *not* the tasty morsel he had in mind, and goes away. But there is a real meaning behind all this bluff, since the secretion of the fire-belly's skin is quite poisonous and caustic as well, so that no animal will knowingly seize it. In captivity the fire-bellies soon learn that their captor means them no harm, and so can hardly ever be induced to perform.

A large bowl in which aquatic plants are growing makes a very good home for fire-bellies. They float for hours among the leaves at the surface, their glittering gold-and-brown-flecked eyes watching every movement above their "pond" in their patient wait for a low-flying insect. They learn to take small pieces of raw beef readily; hence their upkeep in captivity is no great problem, and the duration of their lives is satisfactorily long. When disturbed in the water they are very agile. The tame ones seem to like to have their captor near at hand to reply to their low, musi-

cal croak, but in the wild state the slightest movement by a human being or an animal sends them all diving into the mud, their webbed feet kicking up the silt which settles on their backs as the water clears, leaving them almost completely invisible at the bottom of the pool.

In the breeding season, rough black pads appear on the inner forearm and first two fingers of the male, and he begins to utter his honking call more persistently. Spawning occurs several times during the spring and summer. The male's embrace is lumbar, and the eggs are laid one at a time, being fertilized after they are laid. They are attached to water plants or to debris at the bottom of the pond. They are relatively few in number, only a few dozens being laid, as compared with the thousands laid by some of the Bufonidae and Ranidae. The eggs are relatively large in size, each one measuring about  $\frac{1}{3}$  inch across, compared to the mother's 2-inch body length. In a week the eggs hatch, and the larvae grow to 2 inches in

Fire-bellied toad (*Bombina bombina*). Gerhard Budich





length before autumn, when metamorphosis is complete. The new little creature now shrinks to a  $\frac{2}{3}$ -inch juvenile and at this stage does not yet have the bright ventral colors or the habit of assuming the warning attitude. Gradually the flash colors appear during the second summer, along with the warning attitude, but full adulthood is not reached until the third year.

Fire-bellies are especially active at night, but even in daytime they move about. They sometimes leave the water to feed on worms and small insects on the banks or to hide among stones. In winter they leave the water entirely, burrowing in soft ground nearby until they are below the frost line. This species does not occur in high mountains, and is seldom found more than eight hundred feet above sea level.

In southern Europe the variegated fire-toad, *Bombina variegata*, is found at higher altitudes. It is yellow beneath instead of orange, and it often lives in temporary pools beside a road, while the northern fire-belly frequents permanent ponds in the plains.

In Asia occurs the "giant" of the genus, *Bombina maxima*, a very handsome toad reaching a length of 3 inches. Its habits are very much like those of its European relatives, but it is said to be rather inactive, so that it can easily be caught in the hand. In this species the orange color develops as soon as the tail of the tadpole is partly reabsorbed; hence the full warning coloration is present almost as soon as the larval stage is passed.

Still another fire-belly, *Bombina orientalis* (Plate 23), is found in mountain streams along the coast of Shantung, China, and in Manchuria and Korea. Not much is yet on record as to its habits.

The midwife toad, *Alytes obstetricans*, is known from Belgium south to the Pyrenees. It displays one of the most peculiar breeding habits yet to be observed in amphibians. Between April and August in the breeding season, several males gather around a "ripe" female—on land, never in the water. The male who is successful in grasping her around the waist now proceeds to stroke her cloaca, thus inducing her to extend her hind legs to make a receptacle for the eggs, which are quickly laid. These appear as a long, double string, twenty to sixty rather large ones making up a set. After the male has fertilized them, he shifts his grasp forward to the female's head and pushes his hind legs through the egg mass until the strings of eggs are closely wound around the hinder part of his body. The female now goes off, freed of all responsibility for the further fate of her eggs. The male retires to his hole until nightfall, when he goes out in search of food, and also to dampen the eggs in



Midwife toad with eggs (*Alytes obstetricans*).  
Hans Rosenberg

the dew, since they must absorb sufficient moisture to swell the protective layer of jelly around them. Occasionally he enters the water with the eggs still in place around his body, but comes out by dawn to pass the daylight hours in his burrow in the ground. In about a month, when the larvae are nearly ready to hatch, he instinctively goes to a pool, where the larvae soon emerge and swim away, thereby ending their father's duties as egg caretaker. Although the young are in a rather advanced stage when they are hatched, their metamorphosis is quite slow, and they are not ready to leave the water as young frogs for at least a year.

They do not make very exciting pets, as they crowd together in the back of the vivarium or under a stone. When they come out at night to hunt for worms and insect larvae, their pale grayish colors and languid motions make them appear almost like slow-motion pictures.

In the wild state, midwife toads show considerable adaptability to altitude range, being found from near sea level to mountainous slopes at a height of seven thousand feet, where the ground is frozen for nearly nine months in every year.

The genus *Discoglossus*, for which the family was named, is likewise found in Europe, from southern France through Spain into northwest Africa, as well as on Sicily, Sardinia, Corsica, and some of the smaller islands off the southern coast of Europe. The breeding habits of this frog are more normal than those of *Alytes*, since the eggs are laid in a pool, where the whole mass sinks to the bottom after fertilization. These eggs are smaller than those of the midwife toad, the female laying as many as a thousand in a season. Development is rapid, the froglets being able to leave the water in a month or two from the time the eggs are laid. The adults often hunt on land, but they are perfectly at home in the water and





Variegated fire-bellied toad (*Bombina variegata*). Senckenberg Museum

can swallow their food when submerged. They are attractively colored in tints of yellowish, red, or brown, often with some dark, light-edged spots. The iris is golden above and dark brown below, with a dark streak through its center.

## The Spadefoots

(Family *Pelobatidae*)

Members of this family are widely distributed over Europe, northwestern Africa, southern Asia, and North America. Some of them are noted for their ability to dig, which they do by means of the "spade," a crescent-shaped horny projection on the side of the foot. *Pelobates fuscus* (Plate 24), the spadefoot toad of Europe, is found from Belgium to Persia and from southern Sweden to Italy, usually staying in sandy areas where it can dig a deep hole with a minimum of effort. Even if the sand caves in over its head, this does not trouble it at all, but rather adds to the effectiveness of its concealment. It comes out

after nightfall to hunt for insects and worms, hence is seldom observed by human beings even in localities where it is quite common. Sometimes when it is captured it utters a shrill cry that in some instances may startle its captor into abandoning it. But if it is not released at once, its skin becomes covered with a dermal secretion having somewhat the smell of garlic. This fact accounts for its German name of "Knoblauchskröte" (garlic toad). When gently handled a captive spadefoot will not give off this peculiar-smelling exudation nor cry out when picked up.

In the spring at breeding time the male goes to a pond and utters a sort of clucking call, which apparently charms the female and causes her to come to him. The eggs are laid in gelatinous strings, each containing several thousand eggs. They are entwined among the stalks of water plants. Hatching takes place about the fifth day after the eggs have been laid, but the larvae are very underdeveloped, lacking a tail and gills, and measuring only  $\frac{1}{8}$  inch in length. On the day following hatching a tail begins to grow, and two days after that the fringed outer gills sprout. In



about ten days these give way to new internal gills. After three months the tadpole may have grown to a length of 4 inches and acquired legs, and it is then ready to leave the water. When fully grown a female spadefoot is about 3 inches long, and the male about 2½ inches.

The mud-diver, *Pelodytes punctatus*, lives in southwestern Europe. It prefers to stay close to water, into which it leaps if danger threatens. Its skin is covered with warts, and its color is subject to considerable change, a single individual turning from brown to gray, sometimes spotted with green and at other times without spots. At breeding time the male clasps his mate around the pelvis, with his forearms parallel

beneath the female's body and his elbows touching, and holds this position until the eggs have been deposited and fertilized. The adult is not over 1½ inches in length, and the tadpoles do not usually exceed 2 inches. In other respects they are much like those of *Pelobates*, just discussed.

The genus *Megophrys*, from southern Asia and the East Indies, has many odd-looking members. *Megophrys nasuta* from Malaya owes its specific name to a long projection of skin on the tip of its snout. It also has a "horn" of skin on each upper eyelid, suggesting some of the horned frogs, genus *Ceratophrys*, of South America. Its very wide mouth and strong jaws indicate that it is probably cannibalistic. It is

Painted frog (*Discoglossus pictus*). Robert S. Simmons







Asiatic horned frog (*Megophrys nasuta*). D. Dwight Davis

"cat-eyed"—that is, the pupils of its eyes are vertical—which tells us that it is nocturnal. It has a bony shield in the skin of its back, reminding us still further of some species of *Ceratophrys*, which likewise have a bony dorsal shield. The resemblance of these two genera is only external, however; there are many structural differences to separate them.

The larvae of several species of *Megophrys* have developed "umbrella mouths," the lips having been modified into a sort of funnel which assists the tadpole in feeding. In *Megophrys montana* from the Malay Peninsula the tadpoles float upright in the water, seeming to hang from their large mouths, which also apparently act as surface floats. Inside the expanded lips there are radiating rows of minute horny teeth, which are used in scraping the leaves of water plants for the microscopic plant and animal life that make up the tadpole's food.

The Asiatic *Scutiger schmidtii* may call during the day, but the call is given with increased intensity at night. A real courtship ensues at the appearance of a female, the male apparently enticing her with his

voice. Sometimes several males have been observed calling to a single female. After she has selected one of the attentive candidates for her mate, the clasp is pelvic, the male's right hand being placed over his left with all his fingers curved. Mating takes place among the roots of bamboos, the couple moving into a nearby mountain stream for the deposition and fertilization of the eggs. There are two nuptial patches of spiny tubercles on the male's chest that stimulate the female to lay when they are brought into contact with her anal region.

Other Old World frogs of Pelobatidae have similar nuptial spines, as do some frogs of other families.

The genus *Scaphiopus* comprises the North American spadefoot toads, related to but not identical with the European spadefoot. There is a single species found in the eastern United States, *Scaphiopus holbrookii*, but several live in the southwestern states and Mexico.

The skin of adult spadefoots is moist, smooth, thin, and very glandular, secreting a peppery-tasting, musty-smelling substance. The males produce more



of this secretion than do females, which is odd, because the females seem to have the greater need of its protective powers when they are carrying a heavy load of unlaidd eggs. It also seems peculiar that most kinds of thin-skinned spadefoot toads live in the southwestern United States, where the air and soil are exceedingly dry, and where evaporation of body fluids through the skin would go on at a disastrous rate if the toad remained for long periods in the desiccating rays of the sun. They avoid this by being nocturnal and fossorial. A spadefoot can burrow for several feet underground if the upper surface dries out too much. It may stay in its burrow for some weeks or even months, until the next good rain comes. Even at night, it has been noted, they come out to feed much later in dry weather than in wet. They are

secretive and shy even under cover of darkness, and may live in a region for years without ever being noticed by their human co-inhabitants. They eat insects and small arthropods in considerable numbers. They often return to the same burrow on several successive nights, which proves that their sense of direction is well developed. If the mouth of their burrow is covered with soil, they come up to unplug it and allow free access of air to the inside. This happens only during warm weather. In winter the spadefoot remains torpidly in the burrow, not requiring much oxygen in its lethargic state, and not caring whether its entrance hole is open.

Like the eastern spadefoot, the several western forms breed and lay their eggs in water. Their problem is to find water in which to breed in the semi-

Eastern spadefoot toad (*Scaphiopus holbrookii*). Jack Dermid







Asiatic horned frog (*Megophrys nasuta*). D. Dwight Davis

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Eastern spadefoot toad (*Scaphiopus holbrookii*). Jack Dermid







Eggs of eastern spadefoot toad (*Scaphiopus holbrookii*).  
Charles E. Mohr

desert region in which they live. They have adapted themselves to this condition by being ready to breed at any time during warm weather a few hours after sufficient rain has fallen to fill some of last year's dried-up ponds to a depth of two feet or so. At the approach of dusk, the males go to the recently formed pools, and the first one at the pool gives a very loud, hoarse cry, which is the signal for all other males within hearing to go toward it. Within a few minutes there are many males floating sprawled on the surface and giving their call, which is often audible to human ears at a distance of two miles over the prairie. The females also respond to the call, and the louder it becomes, the more they are attracted. A male in the darkness will seize any frog he touches, but if it responds with a croak, he knows it is a male and continues his search until a noncroaking toad assures him he has a female. An hour after darkness has fallen, mated pairs are to be seen everywhere. The

eggs are laid before day comes, and they are placed in small clusters fastened to vegetation, the pairs moving about from one spot to another in order to separate their complements of eggs.

The eggs develop more rapidly than those of almost any other known tailless amphibian. In two days of normal temperature they hatch, and the tadpoles begin to feed on the third day. The tads of Hurter's spadefoot, *Scaphiopus hurteri*, actually double in bulk in their first twenty-four hours, and nearly double in bulk again on the next day. After that the rate of growth slows a little, but they continue to grow quite rapidly, for on the twelfth night after the eggs are laid, some of the tiny spadefoots emerge from the pool. But sometimes six weeks or more elapse before the froglets' emergence. This great difference has been explained in an interesting way.

When rain water fills the bed of a long-dry pool, there is sometimes not very much food for tadpoles there. Some organic matter may be washed in, but the amount of this varies greatly, so that the nutrition is good for the tadpoles in some years and insufficient during others. If food is adequate, their growth is rapid and normal; but if it is insufficient, they are forced to swallow mud from the bottom, getting what little nourishment they can from that source, and their growth rate is much slower.

If nutritional conditions for them have become very inadequate, some kinds of spadefoot tads band together and cooperate in securing food—a most unusual practice for an amphibian. The tadpoles form a dense school and swim together like a school of fish. The school moves slowly over the bottom, each tadpole lashing its tail violently so that a current is created among the mass of dead leaves and debris and passes out in a stream in the wake of the school. Each tadpole takes what it can get from the organic material thus put into motion. Sometimes one is killed by a water beetle or some other predator stirred up in the mass, and then it is immediately devoured by its companions. If several tadpoles are killed by the overcrowding, the survivors suddenly turn cannibal and attack and eat each other. This behavior is biologically essential, since all the tadpoles cannot complete their aquatic development before the water disappears and leaves them all to die. As it is, the survivors have a better chance to win their race with evaporation and ultimately to reach adulthood. But even if the race is not won in this particular pool, and if all the tadpoles are killed by evaporation of the water, their bodies become part of the material of the dry pond bed, and at the next season's rain pro-



vide very acceptable food for next year's tads. The surprising thing is that in this very shallow pond, the later tads that eat the remains of their predecessors metamorphose at about one-half the normal size, and leave the water several days earlier than tadpoles of an adjoining pool that has never been subjected to desiccation. Furthermore, it has been proved that the growth and development of living tads is greatly stimulated by a diet of dead tads when the water level in the pond is falling dangerously low.

Another condition for aggregation has been observed for spadefoot tads. If the water becomes very low just before the tads are able to leave the pool, they come together into nonfeeding groups and fan the bottom with their tails. Thus they can scoop out a little depression in the mud, into which the last water in the pond flows as evaporation progresses. The surface exposed to the air in such a depression is lessened, and as evaporation is thus cut down, the little time by which the water supply is prolonged sometimes is enough for the tadpoles to transform completely and become independent of water. An hour one way or the other has been known to make the difference between the survival or destruction of the thousands of tadpoles congregated in one small, drying pond.

A third kind of social aggregation has been noted in Hurter's spadefoot. Tadpoles nearing the time of emergence form thick nonfeeding aggregations that swim slowly about until darkness comes. Then suddenly as though with one mind they all climb out on the bank, thousands coming out of the water in a few minutes. Their tails then shrivel quickly and other changes come about, so that in a few hours each one has become a tiny adult in form. Before daybreak they usually scatter, and few can be seen near the pool by the next morning. It is not known how long it takes them to attain breeding size. When fully grown, however, they are approximately 4 inches long.

The eastern spadefoot, *Scaphiopus holbrookii*, does not usually have to face the problem of drying ponds during its larval cycle. Nevertheless it becomes a true troglodyte in time of drought, staying buried in the ground for weeks or even months. The first good rain brings it out of its burrow quickly, however, and soon the nearest pond is ringing with the penetrating voices of the males, which have been likened to the cawing of crows. The chorus from near at hand is deafening, and as it may continue for two or three days, the nerves of human beings who live within hearing distance are worn thin long before the toads have finished their calling. Masses of eggs numbering from

1000 to 2500 are deposited in bands wrapped around water plants. These hatch in from 1½ to 15 days, depending on the temperature, and the tadpoles develop much more slowly than do those of the western spadefoots. The maximum size of the eastern form is 2⅞ inches. It is found in sandy lowlands from southern New England to Florida, and west to Missouri, Arkansas, and Louisiana. It has very prominent pop eyes, with vertical pupils, and a fat, soft body with short legs. The permanent shovel on the inner border of each hind foot is a most effective digging implement. If you place one of these spadefoots in a vivarium partly filled with dirt, you will see it squat on the surface, and after a slight rocking motion of its hind legs, it will gradually vanish below the surface almost without perceptible motion. But if you place a finger under it, you will feel the vigor with which the spades on its feet act to dislodge the soil and push it to either side, and you will understand how a tunnel beneath and behind the toad is very quickly excavated.

Couch's spadefoot, *Scaphiopus couchi* (Plate 25), lives in grassy plains and semi-arid regions of the southwestern United States and adjoining parts of Mexico, where it survives drought by burrowing deep into the ground. Its voice is a groaning bleat, suggesting that of an unhappy sheep.

Eastern spadefoot toad (*Scaphiopus holbrookii*), burrowing in mud. Maslowski and Goodpaster







Cliff frog (*Syrrhophus marnockii*). Charles E. Mohr

## The Leptodactylids

(Family Leptodactylidae)

The members of the family Leptodactylidae are extremely different in appearance from one another. A toad is always recognizable as a toad the world over, but we have to depend upon certain similarities in anatomical structure, often apparent only upon dissection, to link together the many different kinds of leptodactylids.

The West Indian and tropical American regions teem with frogs of this group, while some are found in Australia—a prize example of discontinuous distribution. Zoologists like to think of related animals as living in nicely contiguous regions of the globe. But the leptodactylids did not read the books, and they appear not only in tropical America but also in the oldest continent, Australia, which is populated presumably by the most ancient forms of life, forms that have mainly died out on the other, newer continents. Hence we are led to believe that the leptodactylids have a very old family tree—older by far than that of the true toads, family Bufonidae, or the true frogs, family Ranidae, neither of which occurs in Australia.

The genus *Leptodactylus* contains some of the largest examples of the family. A healthy adult of the mountain chicken, *Leptodactylus fallax*, from Dom-

inica, tips the scales at two pounds and measures 5¾ inches. It is beautifully colored with rose pink and orange sides and a brown back, and has lustrous gold-veined eyes. The "bullfrog," *Leptodactylus pentadactylus* (Plate 26) of South America and Panama, grows to the even greater size of 8½ inches. At the breeding season the sides of its legs turn deep orange or red, contrasting with the dark green and brown of the rest of its body. The male has a very heavy black spur on his thumb and other similar ones on each side of his breast to assist in holding the female at mating. Large frogs such as these are relished by anything that can catch them, including human beings, so that really big ones are not plentiful.

While most of the leptodactylids lay eggs in water and produce tadpoles in the usual fashion, one genus, *Eleutherodactylus*, skips the free-living tadpole stage, so that the young emerge as miniature frogs. In the southeastern United States lives the greenhouse frog, *Eleutherodactylus planirostris*, popularly so named because it is frequently found in greenhouses under flowerpots in a humid atmosphere. Between May and September it lays its eggs singly under plant debris or in some dark, damp crevice, but never in standing water. The eggs develop rapidly, and soon a tadpole may be seen twisting around inside the egg. But he does not yet burst through the shell membrane. Instead he stays inside until the gills and most of the tail are reabsorbed by his body; then his arms and legs grow and his mouth assumes the shape of an adult's. At this stage, thirteen to twenty days after being laid, the shell membrane is ruptured, and out hops a tiny but perfect froglet, about ⅓ inch long, able to fend for himself almost as well as his larger relatives can, and in no danger from aquatic enemies that would attack a water-dwelling tadpole. Fewer eggs—twenty-six or less—are produced by the parent greenhouse frog than is usually the rule with spawning frogs, and a considerable proportion of the young survive the metamorphic period, that most dangerous milestone in the life of any young amphibian.

To aid the young frog in escaping from the egg, there is an egg tooth on the tip of its snout with which the egg membrane can be easily slit. This is a true tooth, located at the front of the upper jaw on the premaxillary bone. Soon after it has performed its single function the egg tooth is shed permanently.

Sexual maturity is reached by this frog in one year after hatching. Its maximum size is 1¼ inches. Its close relatives are common in several of the West Indian islands, whence it was presumably introduced into Florida, where it is now well established.



Like many of its relatives, the greenhouse frog has more than one color pattern. Some individuals have a pair of light longitudinal stripes, while others are mottled with irregular brownish markings. At rare intervals a frog is found that has a combination of the two patterns. In a clutch of eggs from a single mother, young with stripes and others with spots may develop. Apparently each frog keeps for life the color pattern with which it comes into the world.

The greenhouse frog is very active in warm weather but more sluggish when the temperature drops below 60°F. In dry weather it burrows into the damp soil to escape desiccation. It is nocturnal and comes out by day only in rainy weather. It stays mostly on the ground but sometimes climbs a few inches on low-growing vegetation. Its call consists of several short, whistling notes, which have been compared to the cheeping of very young ducklings. Ants make up a

large part of its diet, and it also eats small cockroaches, beetles, and other insects.

The barking frog, *Eleutherodactylus latrans*, occurs from central Texas to northern Mexico. It is larger than its relative the greenhouse frog, as a large adult measures 3¾ inches. It is quite toadlike in appearance, with a wide head, heavy body, and rather short legs, and it has the toad's habit of puffing up when in danger. Its common name comes from its peculiar call, which at a distance sounds like the barking of a dog. Its voice has been specially likened to the yapping of a fox terrier. It lives in crevices, under rocks, and in caves among limestone formations, and is not dependent upon permanent water. In fact, it is an awkward swimmer and does not try to escape by diving if surprised near water. It is nocturnal, and is hence not often seen or collected by students of natural history except during its breeding period, when it

Cuban free-fingered frog (*Eleutherodactylus eileenae*). Robert S. Simmons





is less retiring. It has a ventral adhesive disk, which helps it to climb and cling to vertical rock faces; it could not do so by using its toes and fingers alone, since the disks of these are not large or well adapted to an upside-down existence. Breeding takes place during any rainy period between February and May. A single female may deposit up to fifty large eggs in moist cracks of rocky ledges or in caves. The male remains near the eggs until they are hatched, probably in twenty-five to thirty-five days, wetting them with his urine if the soil around them should become too dry. This is the only known instance of parental care in North American frogs. While the young have not yet been reared from the egg to maturity in a laboratory, it seems probable that this frog is not full grown until it is two and one-half or three years old. Its food consists of ants, beetles, and spiders.

The cliff frog, *Syrhophus marnockii*, found only in Texas, is adept at flattening itself to fit into rock crevices by day. After dark it emerges to hunt for insects and other small prey.

In the West Indies and in tropical America the genus *Eleutherodactylus* is represented by a prodigious number of species. In western South America in particular, the number of different forms appearing in a single region is astonishing. In Colombia alone some thirty different species have been reported. *Eleutherodactylus unistrigatus* is one of the commonest of all species, occurring in considerable numbers in parts of Colombia, Ecuador, and Bolivia. Having large disks on fingers and toes, it suggests a *Hyla* in outward appearance. Inside the mouth, however, it has a small toothlike projection at the tip of the lower jaw—a structure not present in the Hylidae.

In Brazil I found the "nest" of Guenther's frog, *Eleutherodactylus guentheri*, in a clay bank by cutting into the seemingly solid earth with a machete. The tadpoles were in a frothy, foamlike fluid, and were nearly ready to emerge. I took them to the laboratory, and in a day or two the tiny frogs, no larger than a housefly, were hopping around the vivarium, gladly accepting the aphids and other small prey I offered them. The adult is only 2 inches long, and these mites, if all went well, would attain that size in a year and begin to carry on the cycle of life in their turn.

Several distinct patterns, something like those found in the greenhouse frog, occurred among my Guenther's frogs. Some of them had a dark X mark on the back, others had parallel dark lines down the sides, while still others had alternating squarish light and dark spots. Some of these color varieties

were given separate scientific names by zoologists who failed to realize the true variation of this frog's pattern, but it has been proved that all these color patterns may appear in any one brood of actual brothers and sisters. Therefore we may correctly call all of them Guenther's frogs.

A frog that fights seems almost a contradiction in terms, for most frogs are considered to be the personification of timidity. But some of the South American horned frogs of the genus *Ceratophrys* are as "game" for their size as anyone could wish. I kept some Wied's frogs, *Ceratophrys varia*, in my apartment in Rio, and whenever I approached their cage, they faced me and leaped at me belligerently, although they were only 3 inches high. I knew of their pugnacious disposition before I tried to feed them; otherwise my fingers would have been well pinched. Even after their bountiful meal of worms and beetles, I had only to present them with my large metal feeding forceps to have one of them leap and seize the end of the instrument in its very considerable jaws, to hang suspended in the air for some moments before allowing itself to drop back into its cage. At times they would merely inflate with air, grunting a harsh "ah-ah-ah-ah" as long as the fancied danger threatened. They liked to burrow in the moss at the bottom of the cage after a good meal. Their feeding habits showed an inclination toward cannibalism. Their extremely wide mouths and steel-trap jaws are certainly useful in subduing larger prey than the beetles and other small invertebrates that are the customary food of the majority of the other kinds of frogs.

The "horn" of Wied's frog is merely a curious triangular prolongation of the edge of the upper eyelid. It is by no means hard or sharp, as it is only a flap of skin, but perhaps it makes the wide head appear even wider and therefore less acceptable to the forest creatures that would normally dine on these frogs. There are hornless horned frogs too, in which the upper eyelid is smooth or at most is studded with a few flattened tubercles. However, the skulls and other internal anatomy of horned and hornless *Ceratophrys* agree closely; hence we see that the degree of development of the horn is not of sufficiently great anatomical importance to split this group into several genera.

Wied's frog is truly armored, however, by a dense bony shield extending over its back and head. This bony plate would make it a very uncomfortable mouthful for an enemy to swallow. Again, some *Ceratophrys* lack this shield yet seem to be as numerous as the shield-equipped ones. None of the group occurs in very great numbers, and in fact its

[continued on page 89]



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1. Since the food habits of caecilians have generally not been described, this is interesting evidence that *Siphonops annulatus* will devour earthworms. (Carl Gans)



2. The São Thomé caecilian (*Schistometopum thomense*), one of the most brightly colored members of its family, may be a foot in length, although its diameter seldom exceeds half an inch. (G. F. Kims)





3. Sometimes found in abundance, in a breeding pond for several days in early spring, the spotted salamander (*Ambystoma maculatum*) hides for the remainder of the year, seldom venturing out by day. (Robert S. Simmons)



4. The marbled salamander (*Ambystoma opacum*) has a very wide range in the United States, being found from New England to northern Florida, and westward to Texas. Its light markings often have a silvery gleam. (Robert S. Simmons)





5. The young red-spotted newt (*Diemictylus viridescens*) emerges from the water with a red or brownish skin (and is then often called the red eft) but after a short stay on land, it returns to water and becomes a dull green, with a lateral row of red spots. (Robert S. Simmons)

6. At breeding time the male Algerian newt (*Pleurodeles poireti*) has an extremely rough skin resulting from many small rounded particles embedded in it. (Robert S. Simmons)









7. The male of the smooth newt (*Triturus vulgaris*) is of uncommon beauty during the breeding season, his graceful swimming display being accentuated by the brightly colored, finlike crests on body and tail. (John Markham)



8. Found in Japan, the Japanese newt (*Cynops pyrrhogaster*), as it is often called, is also native to parts of eastern China. In captivity it is a voracious feeder, and soon learns to accept shreds of meat from its owner. (Constance P. Warner)



9. Jordan's salamander (*Plethodon jordani*), also called the red-cheeked salamander, is found only in the Great Smokies of North Carolina and Tennessee. It lives in forested regions and is seldom seen. (Robert Simmons)

10. Although the red-backed salamander (*Plethodon cinereus*) sometimes has a red dorsal stripe (as shown here), and sometimes is entirely lead-colored, we now know that these are phases of the same species. (Robert Simmons)







11. The delicately colored Carolina spring salamander (*Gyrinophilus dunnii*) lives in mountain streams where Tennessee, Georgia and the Carolinas meet. In its native waters, it is a strong swimmer. (Charles E. Mohr)



12. The yellow-blotched salamander (*Ensatina croceator*), found well up on coastal mountains of southern California, hides by day and searches for food on rainy nights. (John H. Tashjian)



13. The female  
long-tailed salamander  
(*Eurycea longicauda*)  
coils around her eggs  
to protect them until  
hatching is ended.  
(Charles E. Mohr)







14. An inhabitant of mountain streams, the black-bellied salamander (*Desmognathus quadramaculatus*) hides under stones in the stream when danger threatens. In captivity it learns to eat any soft food. (Robert S. Simmons)



15. Like its relatives, Gorman's salamander (*Hydromantes gormanii*) is a cave-dweller. Found in Tuscany, Italy, it has been known only since 1952. (Nathan Cohen)



16. Salamanders that climb trees are an oddity. The arboreal salamander (*Aneides lugubris*), found near the Pacific coast of the United States, seems equally content in trees, on the ground, or burrowing into soil. (Charles E. Mohr)



17. A sphagnum bog or woodland pond is the preferred habitat of the four-toed salamander (*Hemidactylium scutatum*). Only one other American salamander, the dwarf (*Mamulus quadridigitatus*) has four, instead of five, toes on the hind foot. (Charles J. Stine, Jr.)

18. The northern red salamander (*Pseudotriton ruber*) appears in clear brooks from New York to Alabama. The bright red or orange tones may darken to a purplish brown with age. (Robert S. Simmons)







19. The olm (*Proteus anguineus*), found only in lightless caverns in the Carpathian Mountains of Dalmatia, has been intensively studied. Its normally white skin turns black under the stimulation of light when it is kept in the laboratory. (Charles E. Mohr)



20. The broad-striped dwarf siren (*Pseudobranchius striatus*) dwells in the mud and floating vegetation of cypress swamps and marshes in the southeastern United States. Its weak fore and hind feet have only three digits apiece. (Robert S. Simmons)



21. The "tailed" frog is a misnomer for *Ascaphus truei*, since the projection at the end of the body is an external cloaca that becomes a copulatory organ at breeding time. (Robert S. Simmons)





22. The Surinam toad (*Pipa pipa*) is extraordinary because, in breeding, the eggs are pressed upon the spongy back of the female after fertilization by the male. The skin swells rapidly and thus encases the eggs while they develop. (Raymond J. Cummins)





23. The oriental fire-bellied toad (*Bombina orientalis*) lives in mountain streams near the seacoast of northeastern China, Manchuria and Korea. Like its relatives in Europe, it attaches its eggs to the underside of submerged stones. (Charles E. Mohr)



24. The European spadefoot (*Pelobates fuscus*) spends most of its time in its underground burrow. At breeding time, however, the male enters a pool and calls to his mate from below the surface. (Robert S. Simmons)

25. Another burrower is Couch's spadefoot (*Scaphiopus couchii*) found in the southwestern United States and most of northern Mexico. It digs by means of a spadelike growth on the hind foot, and can quickly disappear in sandy soil. (Willis Peterson)





26. Prized for the delicious meat of its large hind legs, the South American bullfrog (*Leptodactylus pentadactylus*) is extremely wary throughout its range over most of South and Central America. (Robert S. Simmons)



27. The upper jaws of Bell's ceratophrys (*Ceratophrys ornata*) have large dagger-shaped teeth that may serve as defensive weapons, as well as aggressive means of overcoming other frogs which it devours. (A. van den Nieuwenhuizen)







28. The Catholic frog (*Notaden bennetti*) so named because of the cross marking on its back, inhabits the very dry areas of New South Wales and southern Queensland, appearing above ground only after rain. It exudes a milky poison when roughly handled. (Allen Keast).

29. The European green toad (*Bufo viridis*) changes color as light, heat and humidity vary, sometimes passing quickly from a green-spotted creamy color to a pasty gray. Such changes may serve as camouflage. (Erich Sochurek)







30. Because of its great appetite for beetles, the **marine toad** (*Bufo marinus*) has been exported from its native tropical America to nearly all sugar-producing areas to combat the sugar beetle. (Russ Kinne)



31. The **Cuban toad** (*Bufo ephippium*) has a thick skull and a pointed snout. Using his hind feet, he burrows a few inches down and rests at the bottom of the shaft, his bony head blocking it completely. (Constance P. Warner)





32. Blomberg's toad (*Bufo blombergi*) discovered only a few years ago, is probably the giant of its family, measuring over 9 inches in length. It lives in the foothills of the Cordillera of southwestern Colombia, where 150 inches of rain falls annually. (Charles E. Mohr)

33. One of the handsomest of the toads is the smooth-sided toad (*Bufo guttatus*), found in northern South America. It has rich brown stripes against a creamy ground and is less squat than many of its relatives. (Edward Elkan)







34. Fowler's toad (*Bufo fowleri*) "sings" with its vocal sac puffed out. It utters a short unmusical bleat, but in a chorus the din is audible for some distance. (Charles J. Stine, Jr.)





35. The cricket-voiced toad (*Ansonia grillovoca*) is more aquatic than its relatives, the true toads. It lives in streams on Balabac in the Philippines, where the webs between its toes serve it well in battling currents. (Robert F. Inger: Chicago Natural History Museum)



36. Occurring from Kansas to southern California and well into Mexico, the red-spotted toad (*Bufo punctatus*), seldom seen outside of its burrow, is about 3 inches long. (Nathan Cohen)



37. The Mexican marbled toad (*Bufo marmoratus*) displays considerable sexual dimorphism, the females having a broad stripe down the back, with paired dark brown spots on either side, whereas the male (shown calling) has a plain ground color without stripes or spots. (William E. Duellman)







38. The American toad (*Bufo americanus*) may often be confused with Fowler's toad, (Plate 34), and in fact the two may hybridize. Here a pair are in amplexus, the male on the female's back waiting to fertilize the eggs as she deposits them. (Robert S. Simmons)





41. The three-striped arrow-poison frog (*Dendrobates trivittatus*), found in northern South America, reaches a length of nearly 2 inches. Its pattern conceals it among the grass in wet forest clearings. (Edward S. Ross)

39. After hatching, the tadpoles of the two-toned arrow-poison frog (*Phyllobates bicolor*) affix themselves to their father's back by their mouths, and cling there until they have undergone larval development. The father "dunks" them to restore needed moisture to their skins. This and the six following species secrete poison that the Indians use to poison their arrows. (Edward S. Ross)

40. The golden arrow-poison frog (*Dendrobates auratus*), one of the most beautiful of this group of frogs, is native to forest regions from Nicaragua and Panama into Colombia. Although only 1½ inches long, its poison protects it from its enemies. (Constance P. Warner)











42. The yellow-spotted frog (*Dendrobates flavopictus*) is apparently restricted to the uplands of central Brazil. The voice of the male is a trill ending in a high, soft whistle, repeated several times in succession. (Gualter A. Lutz)

43. Boulenger's arrow-poison frog (*Atelopus boulengeri*) lives at high altitudes in Peru and Ecuador. Its skin exudes poison like that of the Dendrobatidae. (Edward S. Ross)







44. Zetek's frog (*Atelopus zeteki*), from Panama, is a bizarre, long-legged, sharp-nosed amphibian, almost fearless in its jungle home, since its skin is so poisonous that no other animal tries to eat it. A well-treated captive does not secrete the poison. (Robert S. Simmons)



45. The flat-spined atelopus (*Atelopus planispina*) is a high-altitude frog from the cloud forests on mountain slopes of Ecuador. It feeds chiefly on ants. It is said to be abundant in May, when breeding begins. (Edward S. Ross)





46. The New South Wales treefrog (*Hyla genolanensis*) has been newly discovered. It is surprising how many moisture-loving amphibians will turn up in an almost desert area. (Erich Sochurek)



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cannibalism would preclude its ratio to the remaining frog population from ever becoming very high. The size range in this genus is considerable. The Amazonian horned frog, *Ceratophrys cornuta*, is a great brute 8 inches long and nearly as wide, while other lesser known ones scarcely exceed an inch in length when full grown. An infant Boie's frog, *Ceratophrys boiei*, about the size of my thumbnail, glared at me when I picked him up in a forest near Nova Friburgo, Brazil. His little face wore a fierce, perpetual frown because of his long, drooping horns, which somehow suggested frowning eyebrows. Some species, such as Guenther's horned frog, *Ceratophrys appendiculata*, which is found in southeastern Brazil, have a long appendage of skin, suggesting a sting, on the tip of the nose. Needless to say, this horn is as harmless as those on the eyelids.

There is a belief in Argentina that if a horned frog—*Ceratophrys ornata* (Plate 27)—bites the lip of a grazing horse, the horse will die from the bite. No poison exists in the mouth of this frog, and it has probably earned this bad reputation by its extreme aggressiveness and its willingness to attack an animal many times its own size and bulk.

Frogs of the genus *Telmatobius* are found only in the high Andes. Some have become entirely aquatic, living in the icy waters of Lake Titicaca and in nearby lakes less well known to the outside world. The aquatic ones are fat, flabby creatures, with long fingers for feeling out their food in the lake mud. Sometimes they creep about in the reed beds near shore at night, but they are virtually helpless on land. As in many aquatic frogs, their tongues and teeth are reduced or absent, as they find no flying insects to cope with. They are seldom found near the surface, and experiments have proved that they never need to come up for the purpose of breathing. The great baggy folds of skin that make them look as if they were wearing ill-fitting garments several sizes too large must have evolved to increase the surface area of the body and to serve as a respiratory organ replacing the lungs. Since these frogs find their food at the bottom of rather deep lakes, lungs would be an impediment to them, as the contained air would tend to float them up from their safe and satisfactory retreat on the lake floor. Needless to say, these aquatic frogs lead a lazy, inactive existence, with plenty of food for the taking and few enemies to cause them to move swiftly in making an escape. Their land-dwelling relatives have the normal frog form, with proper teeth, tongues, and lungs, and are agile in catching their flying insect food.

In Chile, Gay's frog, *Calyptocephalus gayi*, has



Colombian horned frog (*Ceratophrys calcarata*).  
A. van den Nieuwenhuizen

Escuerzo (*Ceratophrys stolzmanni*). Zoological  
Society of London

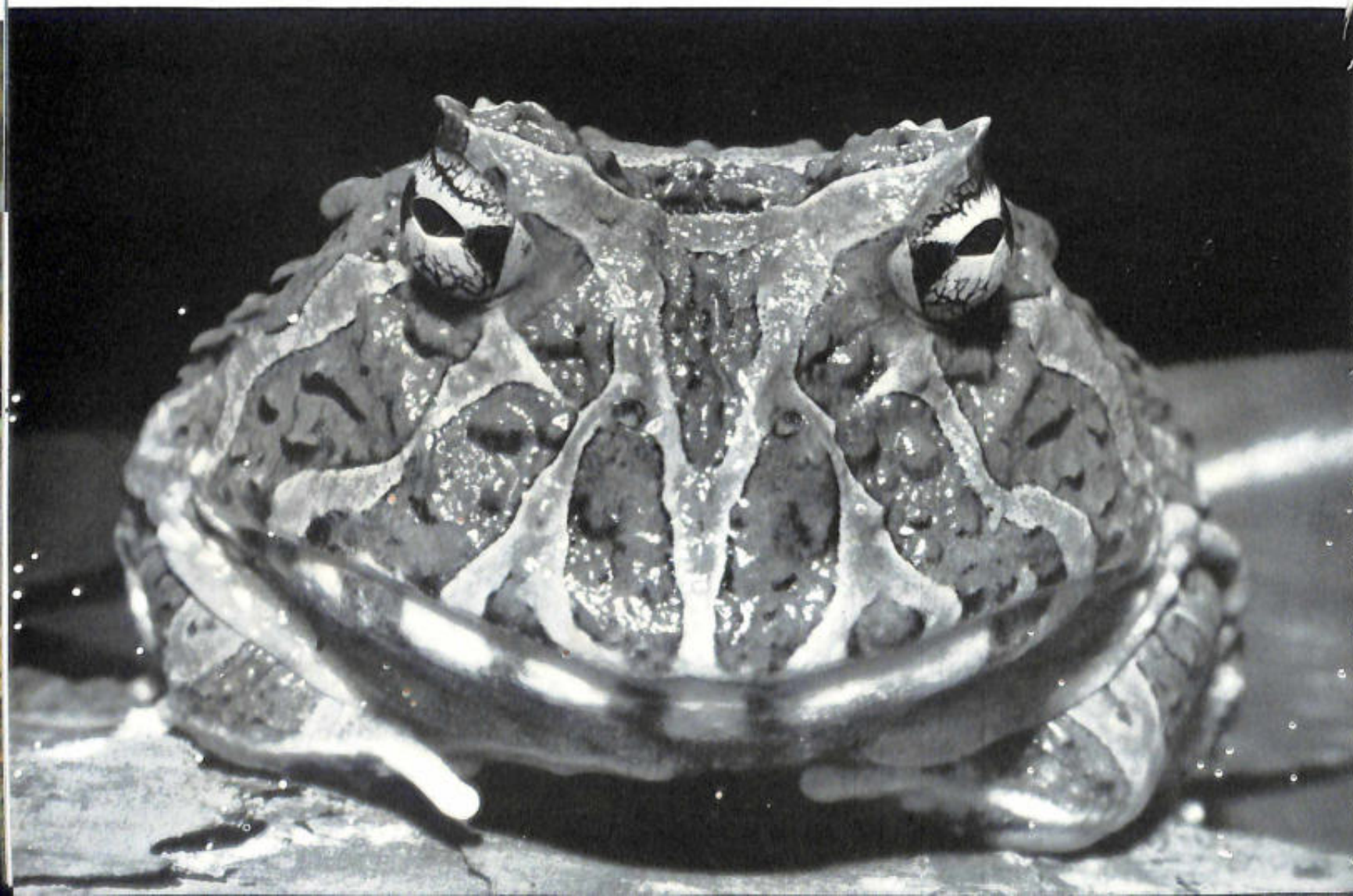






Brazilian horned frog (*Ceratophrys varia*). A. van den Nieuwenhuizen

Colombian horned frog (*Ceratophrys calcarata*). Robert S. Simmons

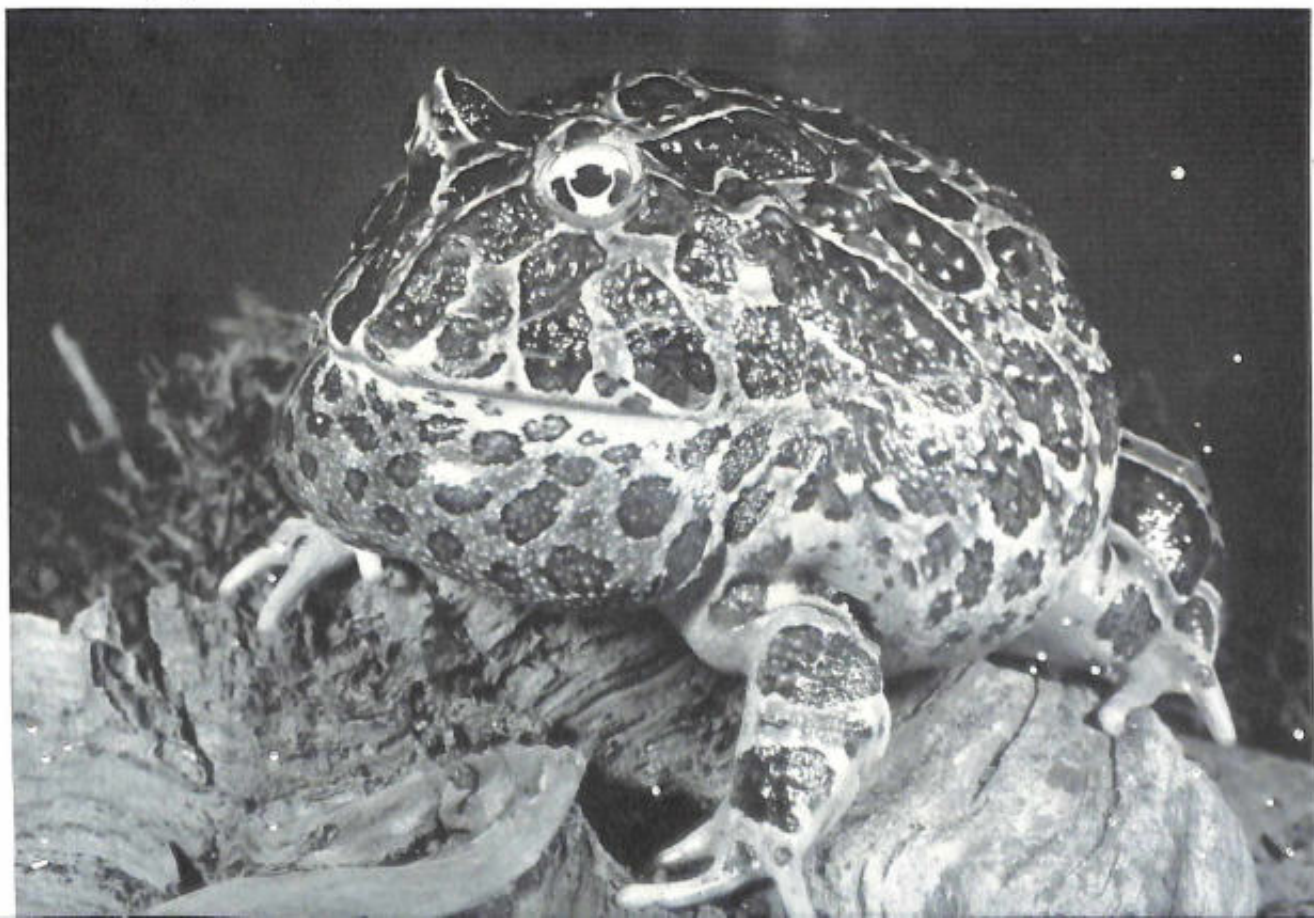






Brazilian horned frog (*Ceratophrys varia*), close-up. R. Van Nostrand and San Diego Zoo

Bell's *Ceratophrys* (*Ceratophrys ornata*), A. van den Nieuwenhuizen





somewhat the same zoological niche as do members of the genus *Ceratophrys* in other parts of South America. It has a huge head, a very wide gape and strong jaw muscles with which to overcome the smaller frogs that probably make up its chosen diet.

Budgett's frog, *Lepidobatrachus asper*, from Paraguay and Argentina, was first made known in 1899, together with the complete study of its development by its discoverer, Samuel Budgett. It too is cannibalistic, having been known to feed upon the granular toad, *Bufo granulosus*.

Some dainty little frogs of the genus *Crossodactylus* live in rock crevices around waterfalls in Brazil. Both males and females are equipped with coarse black

one stage of their complicated existence in the skin of aquatic frogs. They seem to do the frog little damage, however—much less damage than ectoparasites may do to some of the terrestrial toads, which may often be nearly drained of vital fluids by a heavy infestation of ticks or mites.

Many frogs belonging to the genus *Eupsophus* are found in South America. Some that seem to have a tolerance for cold occur on Chiloé Island, off the southern coast of Chile. Those species inhabiting the purely tropical regions of Brazil escape intense heat by lurking around rock ledges from which cold springs emerge. The constant drip of water and its evaporation raise a curtain of coolness behind which these frogs must be very comfortable indeed. Even their tadpoles live on the wet rocks, clinging and moving about with their suctorial, funnel-shaped mouths, and deriving plenty of nourishment from the algae and lichens that plaster the rock surfaces so plentifully everywhere. These little tads are extremely evasive, and can twist their bodies in a sort of sidewise flip to avoid the collector's fingers. Their extremely slippery skins also aid them in escaping, so that I was not able to get a very large proportion of those I wanted at my first trial. *Eupsophus petropolitanus* lives in the mountains near Rio de Janeiro; it is scarcely an inch long when fully grown. The largest tadpole I captured on which a vestige of tail still remained was  $\frac{1}{3}$  inch long without the tail; metamorphosis must take place when the little creature is only a trifle larger. The adult male has a patch of six to ten black spines on his thumb. *Eupsophus miliaris* is a 3-inch frog, considerably commoner than its mountain relative, and frequently found on rocky ledges in the heart of Rio. I caught one at the entrance to a deserted gold-mine tunnel near Ouro Preto in Minas Gerais. A small sluice of water still ran down the middle of the tunnel from somewhere deep inside the mine, providing the coolness that these frogs so evidently prefer.

One of the wariest frogs in Brazil, *Megaelosia goeldii*, is also one of the largest, attaining a length of some 4 inches. Its tadpole is also comparatively large and is adept at dodging among the rocks in swift mountain streams. The adults instantly retreat down a deep rock crevice if they feel the presence of danger. The disparity of size in the sexes is well illustrated in this species, as the females are about twice as long as the males.

Perhaps the hardest to catch of any South American leptodactylids are the dwarf swamp frogs of the genus *Pseudopaludicola*. They are tiny—only  $\frac{3}{4}$  inch long—and they have a most disconcerting habit



Gay's frog (*Calyptocephalus gayi*). Hans Rosenberg

spines at the base of the thumb; they have just two or three of these spines when the frogs are immature, but as many as seven in one species when maturity arrives. This is apparently the only instance on record of an increase in the number of spines—and, of course, in their size—as the frog ages. Several other genera of leptodactylids may have a heavy black spine on the thumb, or sometimes a patch containing a great many small spines, which apparently serve the purpose of assuring the male of a more secure hold on the female while he is fertilizing the eggs. Gaudichaud's frog, *Crossodactylus gaudichaudii*, is found around the rocky streams of Tijuca in the heart of the city of Rio de Janeiro, and also throughout that state and into Minas Gerais to the north. Sometimes an unusually warty appearance is imparted to the smooth skin of these little frogs by the presence of encysted *Cercaria*—parasitic worms that complete



of leaping sideways just as you are about to clap your hand over them. They hop about in the marshy bogs, playing tag with you among the grass stems. At the first try you are lucky to catch one in fifty; after a bit of practice, you may get one in every twenty. I estimated that each leap covered about a yard—some fifty times the frog's length—but I had no opportunity to obtain precise figures. Almost every country in South America has one or more species of this genus.

Some of the handsomest frogs on that continent belong to the genus *Physalaemus*. Some have a curiously marbled pattern that almost suggests the design of gray lichens on rocks. Others are colored orange, brown, and waxy yellow, and resemble in their patterns some of the Microhylidae of southern Asia, although their internal structures place them in completely different families. Most of the numerous species of the genus are between 1 and 2 inches long, and like the preceding genus they have a very wide distribution over most of South America.

An amusing caricature of a ferocious frog is the  $\frac{3}{4}$ -inch Girard's frog, *Zachaeus parvulus*, from southeastern Brazil. The one I picked up in the forest on Tijuca, the lovely wild mountain peak rising from the heart of Rio de Janeiro, merely sat upright in my hand and stared me down with its tiny gold and black eyes, instead of cowering and trying to escape through my fingers. In the vivarium it later accepted small worms and beetles with the enthusiasm of a cat pouncing on a mouse. The tongue of Girard's frog is stalklike in shape and partly free in front, unlike that of most frogs. Thus it can be forced against the roof of the mouth to subdue struggling prey. In structure it is rather close to the tongue of *Craspedoglossa*, another Brazilian frog genus known from two species. These frogs have very wide mouths and heavy muscles for closing them, which probably indicate a cannibalistic habit.

In the other great stronghold of the leptodactylids, Australia, we also find many unusual forms. One of these, *Notaden*, had been considered a bufonid by earlier zoologists because of its toadlike appearance. In the light of recent findings it seems more accurate to include it in the family Leptodactylidae.

Because of the fancied resemblance of its dark dorsal pattern to a cross, *Notaden bennetti* (Plate 28) of New South Wales, Australia, is known as the Catholic frog. While hidden from sight during the dry season, these little amphibians come out of the earth by the thousands after a heavy rainfall. They are active by day, in this habit being exceptional among other Australian frogs, most of which are nocturnal. They move over the ground in short, quick hops. If



Budgett's frog (*Lepidobatrachus asper*). Zoological Society of London and (lower two) Gerald Durrell





Corroboree toadlet (*Pseudophryne corroboree*).  
New York Times

teased, they can puff out their bodies to an absurd size, while rising on all fours with the body completely off the ground and facing their tormentor defiantly. Their food consists largely of the wood-destroying white ants (termites), a fact which perhaps explains their being found near wooden buildings or deserted yards where rotting wood, and consequently a considerable number of termites, are to be encountered.

Their color is often quite bright. The skin is yellowish or greenish, with dark spots having red or white centers. On the parotoid region and all over the back the skin is quite thick, although there are no enlarged glands. Under stress the entire dorsal skin can

produce a copious yellow secretion, which is sufficiently acrid to prevent the toad from being eaten by other animals. After taking off the poisonous skin of this frog the Australian Bushmen have learned to eat their legs and consider them especially dainty morsels. As the toad is only  $1\frac{1}{2}$  inches in length, its tiny legs cannot be of much importance in the Bushmen's diet.

Translated literally, *Pseudophryne* means "false toad" and alludes to this animal's appearance, which caused it to be grouped with the Bufonidae, just like the preceding genus *Notaden*. *Pseudophryne bibronii* does not lay its eggs in water but deposits them under stones in damp places. Egg-laying may take place during six or seven months in the year, whenever sufficient rain falls to wet the ground. If unexpected drought intervenes, the tadpoles may delay their hatching for over three months. They must complete their metamorphosis in water, however. To survive a drought, the adults burrow down into the bed of a pond. At the first shower of rain they begin to croak even from underground, and as soon as the rain has wet the bottom of the dried-up pond they are out in full force to be at the business of breeding. Bibron's frog is not very active and makes little effort to escape if disturbed. It plays dead when placed on its back. Sometimes several hundred eggs are found in the same nesting cavity, but these are the result of several pairs laying in the same place, as ninety eggs, deposited in short rows of a dozen or so, appear to be the number produced by one pair of frogs.

*Phractops platycephalus* makes a burrow extending about a foot underground in damp earth or clay, producing a smooth, round little chamber which just fits the frog's body. It apparently turns round and round in this underground retreat, packing the earth very solidly. Its native name is said to be "co-wari." It is inconspicuously colored olive-gray to brown, and with its nocturnal habits it is very difficult to see when it is out foraging.

*Microphyes fasciolatus* from New South Wales and Queensland is one of the few diurnal Australian species. It lives near the banks of creeks, hiding in moss in the deep shade of overhanging vegetation. It swims well and jumps into the water when pursued. Like some of their South American relatives, the males at breeding time show a patch of brown spines on the first finger of each hand.

*Limnodynastes* is represented in Tasmania and Australia by some half a dozen species, one of which likewise occurs in New Guinea. In three of the Australian species a peculiar specialization of the first finger has taken place. The phalanges of this finger



are much reduced in size, and sometimes individual frogs may be found in which only one phalanx occurs instead of the usual two. But the inner metacarpal bone is extremely long in these three species, so that the first finger is still about equal in length to the second. None of these species has nuptial pads, and all breed in water, where the rough surface of a pad is usually considered essential to the male in securing a grip on the female's slippery body. Thus the loss of the nuptial pads and the reduction in the numbers of phalanges would be a great disadvantage to the frogs if the enlarged metacarpal bone did not compensate, for this bone can function as a nuptial spine, just as it does in the ranid genera *Babina* and *Petropedetes*.

*Limnodynastes tasmaniensis* calls in midwinter (July) when the weather is mild. It breeds in ditches sheltered by overhanging ledges close to the bank and builds a foam nest of gelatinous material produced before the eggs are laid. *Limnodynastes dorsalis* is rarely seen owing to its habit of burrowing, but its eggs may be found in white, frothy, more or less circular floating patches on the water from mid-July to the following April. The ova are small and numerous. None of these frogs exceeds 2½ inches in length when fully grown.

*Crinia* is also from Australia, Tasmania, and New Guinea, and is known from about a dozen species. One of the commonest in the southern part of Australia is *Crinia signifera*, which breeds after a rain at any time of the year. About 150 eggs are deposited in masses fastened to submerged grass stems or stones. They hatch in ten days, and the tadpole remains in that stage for three months before metamorphosing. The males give a call that suggests the chirruping of an insect. Adults live almost entirely in the water, but they tolerate shallow, muddy pools as well as clear mountain streams. The maximum size of a male is about an inch; of a female, slightly larger.

*Crinia laevis* from Tasmania conceals itself in damp soil and comes out only at night. Breeding takes place in late summer (March). The eggs are laid in holes or attached to grass stems near swampy areas which will be flooded during the rains. The eggs hatch in about five weeks in an advanced stage of development, for the larvae have already absorbed their external gills. The song of the male is said to be a short, rasping note that is repeated several times in a few seconds.

The flat-headed frog, *Chiroleptes platycephalus*, can maintain itself in the most arid deserts of central Australia by living underground in burrows and by storing up considerable quantities of water in its own body at the time of the rains.

## The Burrowing Toad

(Family *Rhinophrynidae*)

The structure of the Mexican burrowing toad, *Rhinophrynus dorsalis*, is so different from that of any other known tailless amphibian that it has been placed in a family by itself. Among other peculiarities, its tongue is free at the front, so that it can be protruded like that of a mammal, instead of being attached anteriorly and then reverted in food-getting, as in nearly all other frogs.

Since it is nocturnal in habit, its eyes have vertical pupils which can expand in weak light. It has no external ear and no teeth. The toes are partly webbed, although it is specialized for an anthill existence. A large horny "spade" for burrowing is found at the base of the inner toe, which is further modified by having its tip enlarged for digging.

A large adult is about 2½ inches long. The body is nearly the shape of a hen's egg, the piglike snout and small, pointed head protruding a little at one end. When frightened it puffs up its body and draws its legs underneath it. When one is picked up, it tries to escape by moving backward in its captor's hands; it can do this with surprising force due to a hitching motion of the hind legs that gives to its hind feet the full use of the horny shovels in securing a hold and in backing away from danger.

Its color is dark brown, with a yellow or orange stripe down the back and some smaller yellow spots on the sides. Its skin is smooth and thin, and probably allows some cutaneous respiration to take place. It lives in holes in the ground in thickets and wooded areas in some parts of Mexico and Guatemala. Its native name is "poche," or "po-chi" in Oaxaca. It comes out at night to forage even in the dry season, but it is especially abundant after the rains begin. Its call is guttural and abruptly given, sounding more like the hoarse cry of a bird than that of a toad. It breeds almost as soon as the first temporary rain ponds are filled. While the male habitually calls from his burrow on land, courtship takes place in the water, the tadpoles remaining aquatic until metamorphosis is complete. The eggs are laid in the water in a mass, but they soon separate and float singly on the surface. The tadpole is as bizarre in many ways as the adult. Around the mouth are several long, fringelike barbels, almost suggesting the "whiskers" of a catfish. There are no true lips, such as are found in tadpoles of nearly every other frog family. A large larva, apparently nearly ready to metamorphose, measures 1½ inches in length.





Granular toad (*Bufo granulosus*). A. van den Nieuwenhuizen

## The Toads (Family Bufonidae)

Members of this large family are found in most temperate and tropical parts of the world excepting Australasia, Madagascar, and some of the smaller Pacific islands, from sea level to about 15,000 feet in elevation. There are some thirteen species of the true toads, genus *Bufo*, in North America, eighty-one in Central and South America, three in Europe, seventy-seven plus other genera in Asia, and sixty-four plus other genera in Africa.

Toads are easy to recognize. Their fat bodies and short legs and their hopping gait are sufficient to distinguish them from the more streamlined figures of most other frogs.

Obviously not built for speed, toads rely on an extremely effective protective device that makes speed almost unnecessary. The parotoid glands, located behind the eyes, emit an irritating poison when the toad is frightened or injured. Smaller amounts of the same poison are secreted by glands all over the skin.

No wolf or other predator that has once tried to swallow a toad will ever make that mistake a second time, for the poison from the glands causes a burning sensation in the mucous lining of the captor's mouth and forces it to drop its victim like the proverbial hot potato. One of the large species with an especially potent poison, the Colorado River toad, *Bufo alvarius*, has been known to exude enough poison to cause the death of a police dog that was unlucky enough to seize the animal in its mouth.

Toad poison has its value to others as well as the toad, however. The ancient Chinese physicians added toad skin to their formula for treating heart ailments, and a modern analysis of toad poison has shown that one of the complex proteins of which it is made up contains a digitalis-like substance. And digitalis has long been prescribed by European and American physicians also for the treatment of heart disorders.

Most toads are adept at concealing themselves. Some have sharp, rounded, horny spurs on their hind feet, which act like little shovels in the loose earth and enable the toad to back into a burrow which he excavates with a curious shuffling motion, so that he can drop out of sight below the surface of the ground in a surprisingly few minutes.

Some of the true toads that have the shovel-shaped hind feet resemble the spadefoot toads of the family Pelobatidae in this characteristic. The true toads, however, have enlarged parotoid glands and horizontal pupils, while the pelobatid spadefoots lack parotoids and have "cat eyes" with vertical pupils.

Have you ever seen a toad change its skin? Not many people have, for the process is completed in a very few minutes, although it takes place rather frequently—once in every three to ten days during the warm season. Since amphibian skin does not grow with the growing body (as ours does, for instance), it becomes necessary for the toad, when it has been feeding steadily for a while, to get rid of its tight old skin. Soon the old skin begins to split down the back to make way for the new, larger skin that has formed underneath. The toad then rubs its head and neck furiously with its hands, rolling the old skin into a ball as it does so, and finally kicking its arms and legs free. It then thriftily swallows the ball of old skin, since it contains nutrient elements which are utilized as food. Its new suit is shiny and slightly moist, but it will soon be covered with sand and mud, thereby making the toad less visible on the ground, and so giving it further protection.

Here let me dispel any fears based on an old wives' tale: although the toad's skin is quite warty, it



cannot give warts to anyone who handles it. The true cause of warts in human beings is still unknown, but the toad is definitely not at fault here.

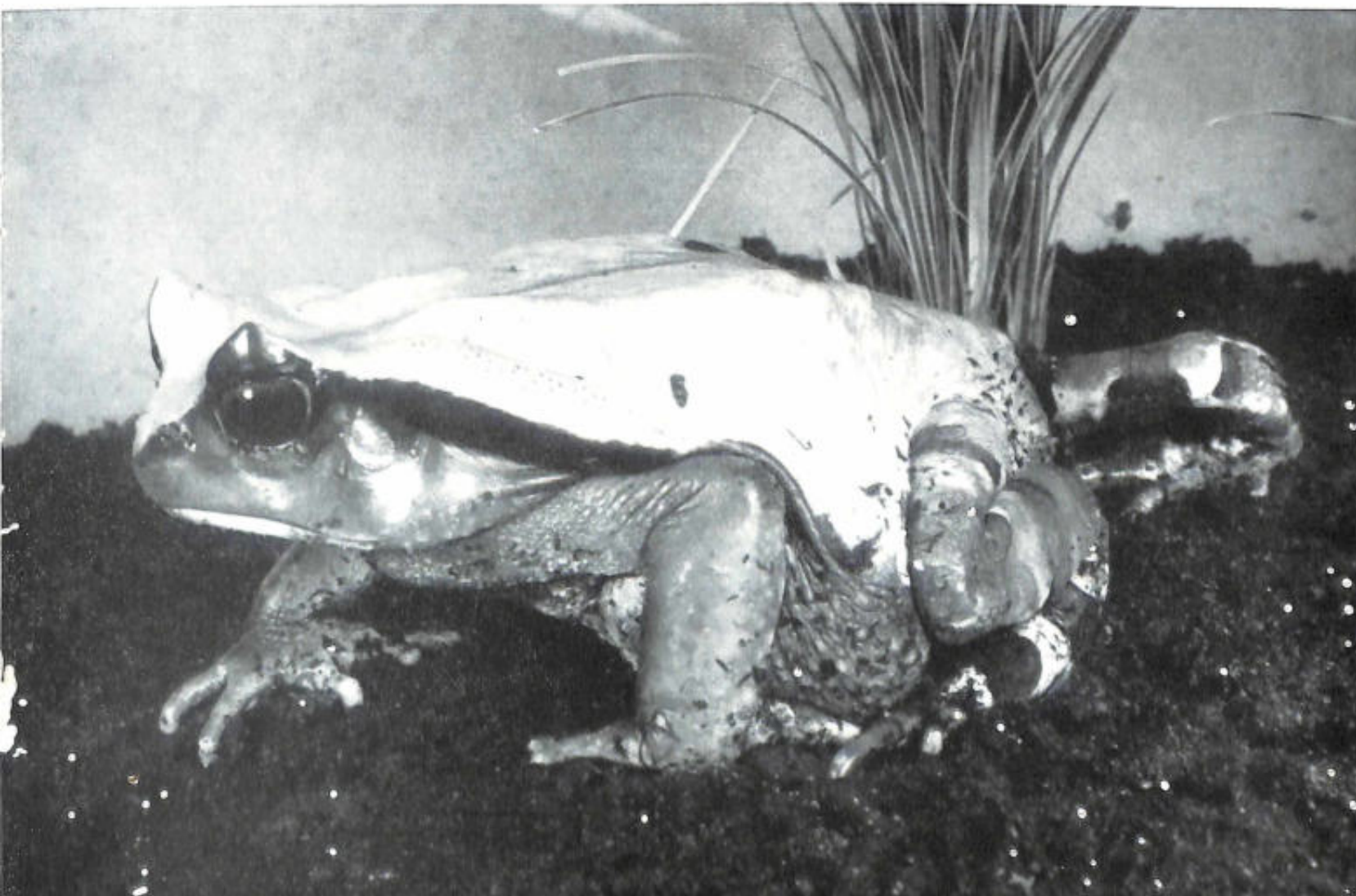
The toad is truly the farmer's friend, for it will eat an almost unbelievable number of insects—mostly injurious beetles—in a single day's foraging. This fact has been recognized by sugar planters, who have imported the giant South American toad, *Bufo marinus* (Plate 30), into every country where sugar is raised. Were it not for its hearty appetite, sugar beetles would soon destroy a large proportion of the world's sugar crop. Thus in Puerto Rico, Haiti, Guam, Hawaii, the Solomon Islands, and other places half a world away from its original home, it can be found policing the rows of cane and protecting a crop worth perhaps a billion dollars a year.

In a lesser way, toads in all parts of the world are beneficial to gardens. While they do not distinguish the "good" insects from the "bad," but take all that come, the numbers of cutworms and beetles that they devour annually is of real importance in keeping down the depredations of these pests. The worth of a single one to a North American gardener or farmer

in controlling the inroads of harmful insects has been variously estimated at from twenty to fifty dollars a year. Its economic value is much greater in insect-ridden tropical countries where every natural check must be used in order to bring nearly all kinds of vegetable products to their harvest.

The modern practice of oiling dirt roads has done a great deal of harm to the toad population. Toads as well as many other amphibians lay their eggs in shallow water, and they frequently resort to roadside ditches to breed. A heavy rain often carries some of the oil into the ditches, spreads an oily film over the water, and prevents the tadpoles from breathing, thus killing them in uncounted millions. Another cause of death among our toad population is the automobile. At breeding time thousands are killed while crossing roads to their favorite pond or ditch. Because of such factors, it is rather unusual now to see or hear toads near any big city. But deep in the country in mid-June, as dusk approaches, a trilling flutelike call comes from a hillside, another answers from a garden, and soon the songs of the toads echo from all sides. The voice has a peculiar ventriloquial quality

Cameroon toad (*Bufo superciliaris*). Gerhard Budich









to human ears, and it is often difficult to locate its owner, especially in heavy undergrowth. The female toad does not have any such difficulty, however, since the call of the male indicates the location of the breeding ground and the presence of a mate ready to fertilize the heavy load of eggs that have formed inside her at the approach of warm weather.

The female toad does not have a loud voice. Some female amphibians, in fact, lack voices entirely, or at most can give only the screaming, open-mouthed cry of fright intended to surprise their captor and cause them to be released. But the male toad makes up for what his spouse lacks in volubility. Toad calls have been recorded on oscillographs and carefully analyzed; consequently we know that each species has its own characteristic pitch, tempo, and periodicity of call. Naturalists can often imitate quite well the purring trill of some kinds of toads, and it is interesting to circle a pond while giving the toads' call from just out of sight, and getting an immediate response from the dozens—or hundreds—of individuals that have congregated there.

The voice may also act as a defense mechanism. The screaming of a captured toad has just been mentioned. If you pick up a toad and hold it under the armpits, leaving its hind feet unsupported, it will usually begin a sort of hiccupping protest, its throat and stomach moving quickly in and out with each sound, giving the effect of intense agitation.

The tailless amphibian does not have a separate air passage to its lungs like that of the higher vertebrates, but must literally swallow air; the air enters the mouth through the nostrils, is passed down the throat by a quick compression of the gular region, and is then sent into the windpipe and finally into the lungs, which are thin vascular structures on the ventral wall of the pharynx. The mating call is produced by the pumping of air backward and forward over the vocal cords, which lie between the lungs and the mouth. The sound can even be produced under water, since the toad keeps its mouth tightly closed when calling. The loudness of the call is increased by the presence of a vocal sac (or by two lateral sacs in some other families of frogs), which is a baglike opening in the floor of the mouth, filled with air and expanded like a balloon during voice production, and acting as a resonator.

The height of the toad chorus lasts as a rule only two or three days and nights, unless unfavorable weather causes it to be discontinued, in which event the chorus is resumed when conditions have improved. Some toads have a longer breeding season—hence calling period—than others, however, and

there are often a few out-of-season croakers that occasionally "sing" into the late summer, long after the rest of their companions have left the pool and gone about their long summer's business of eating and growing. In warmer climates the breeding lasts longer than in colder regions.

Different species of toads living in the same region are known to hybridize when their breeding periods more or less coincide. This adds to the difficulties a student already faces in the correct identification of even some of the more distinct species. Such identification usually depends upon general appearance and bodily proportions, both of which are subject to rather wide variations in most species. These variations cannot always be explained in simple language; in fact, the description of the true relationship of one species to another often requires a statistical formula.

Hybrids between different genera and even families of amphibia are known, although the resulting young seldom grow to maturity. In the laboratory it has sometimes been possible to secure a cross between *Rana* and *Pelobates*, with the offspring exhibiting the characters of both parents. "False crosses" sometimes occur; in these the eggs of the female are activated by the sperm of the male from another family but since the male nucleus fails to enter into the cross, paternal characteristics are therefore not transmitted.

Under the proper conditions toads take well to captivity. They require soft damp soil in which to burrow, an abundance of water, and a diet of small insects and earthworms during the warm season. Curiously enough, they hibernate even in a warm room during the winter; that is, they remain inactive in their burrow for weeks or even months, and usually refuse to eat, proving that hibernation is an inherent seasonal occurrence independent of the temperature at which the animals are maintained. In the wild state hibernation tides the animal over from one warm season to the next, without subjecting it to the impossible task of securing suitable food and shelter in a snowbound, ice-covered world. At the approach of cold weather, the tailless amphibian simply seeks out some secluded spot—a moist hole under a fallen log, or a damp burrow in a stream bank, or even the bottom of a cold stream or a spring—and there awaits the end of winter and the return of warmer weather. At a temperature of 40°F. the frog or toad does not need to breathe, and all its body functions are similarly slowed down, so that it can remain in a self-imposed cold storage that lasts several months and is nicely timed to coincide with the absence of its chief food supply, insects.





Green toad (*Bufo viridis*). Gerhard Budich

In an excessively long, dry summer the toad must go into aestivation to escape another inimical condition, that of drought. The toad seeks out the deepest moisture-preserving crevices in an effort to keep enough humidity in its body tissues to prevent desiccation and eventual death. Workmen excavating old foundations of buildings many feet below ground level have sometimes come upon aestivating toads in blocks of concrete without apparent entrance or exit. This has given rise to the story that toads can live entombed for many years. Experiments have proved, on the contrary, that toads sealed into sandstone boxes that have no openings, but admit plenty of moisture, never live beyond the second year without food. The toad in the cornerstone (unless the whole discovery is a hoax) unquestionably made his way there at the onset of dry weather through some damp crack or channel that was later filled in by the activity of the human excavators.

Toads are probably the most prolific of all amphibians. In contrast to the tiny *Sminthillus limbatus* of Cuba, which lays but a single egg, the female marine toad, *Bufo marinus*, can produce some 35,000 eggs a year, while some of the other giant toads may do nearly as well. Even the southern toad, *Bufo terrestris*, found from Virginia south through Florida and west to the Mississippi River, lays up to 28,000 eggs a year. It is no wonder, then, that ditches and shallow ponds everywhere begin to swarm with small black toad tadpoles a few days after the eggs have been laid. When their bodies have used up the last of the egg yolk which remained with them after hatching, they begin to feed ravenously on the algae and other microscopic life of their stagnant pool. In about a month they have grown tiny arms and legs, their mouths have changed from scraping to snapping organs, their tails have been absorbed, and their lungs have become fully able to breathe air. Now they



leave the water to appear on the banks of the pond in what seems to be millions—each one no bigger than a large housefly, less than  $\frac{1}{2}$  inch in total length. So numerous are they at this time that people who do not know the secrets of their development swear that they have “rained down,” since they usually emerge from the pond just after a heavy rain, which leaves the air moist and thus more acceptable to the toadlets for their first adventure in overland travel. They scatter to some damp, leaf-littered field or thinly wooded area where insect food is plentiful, and remain there to eat and grow until they are old enough to migrate back to the home pond for their own breeding.

Only a minute fraction of the baby toads survive to grow up, because their many enemies take a heavy toll of their numbers. Despite the glandular secretions of their skin, which make them distasteful to the ever hungry small mammals, they are eaten by snakes and turtles as well as by larger frogs and toads, which snap at anything which moves. In the larval stage, countless numbers are attacked by dragonfly larvae and other preying water insects that literally suck the lifeblood out of the tadpole, leaving only the empty skin. And, as already noted, many adults are crushed while crossing highways.

The return to the breeding pond is true migration, triggered by a strong homing instinct. Toads have been captured and taken away from their breeding site, tagged for the purpose of later recognition, and turned loose within hearing distance of the chorus from the chosen pond. Most of them returned there nearly as quickly as the experimenter himself!

Even when not breeding, toads display a high degree of constancy in returning to a favorite retreat every day after hunting. A female of the European common toad, *Bufo bufo*, lived under the front steps leading into a certain English garden for thirty-six years, becoming very tame among the human inhabitants of the house, so that she would come out of hiding to take food from their fingers and have her back scratched.

The green toad, *Bufo viridis* (Plate 29), is known from central Europe to Mongolia and Tibet, and from the Mediterranean islands and the northern coast of Africa. In the Himalayas it has been found at 15,000 feet, perhaps the highest altitude attained by any species of *Bufo*.

Toads are said to react more readily to stimuli than do frogs of the genus *Rana*, for instance. This is probably due to their greater intelligence and also to their greater need for defense attitudes, since their legs are not made for headlong flight from an enemy. Most toads if frightened will inflate the body with air,

thus increasing their bulk by half. Some kinds will even turn broadside, presenting a solid, round, inflated back much too large to be swallowed by the average snake.

The natterjack toad of Europe, *Bufo calamita*, has very short limbs, and when annoyed takes up a butting position, with its body inflated, its forelegs doubled under its lowered chin, and its hind legs fully extended and raised on tiptoe, thus presenting a very unmanageable mouthful to its enemy. Because of its extremely short legs it cannot hop, but it is very agile for a toad and runs in short spurts almost like a mouse.

One of the most beautiful of all species is *Bufo melanostictus*, the black-spined toad of southeastern Asia. The adult is brown and tan, with little black-tipped tubercles. Sometimes the male has rose-colored spots all over the back.

Common European toad (*Bufo bufo*). Hans Rosenberg





In nearly all toads—as Shakespeare noted—the eyes are jewel-like in quality. There are gold, silver, or copper tints on the brown, green, or yellow iris, and each species has its own characteristic color pattern.

Sometimes the skin patterns of young toads or of freshly shed adults are very attractive, consisting of rosettes of dark spots or circles something like a leopard's spots. In old adult males this pattern usually merges into a uniform brown or grayish color. And in general, males are less brightly colored than females in every age group.

A color abnormality found in some kinds of toads is erythrism, which means turning red. I once had a full-grown Fowler's toad, *Bufo fowleri* (Plate 34), from Virginia that had a most beautiful brick-red complexion. This is not too unusual in small toads—I have found several inch-long toadlets with unusually ruddy skins—but I believed that as they grew the skin would darken to the normal brown or gray mottled tone. Not so with this red toad, at least during the several months he was in my vivarium. If anything, his color intensified, and when he settled

Colorado River toad (*Bufo alvarius*). Albert H. Wright



down in the moss, he made a fine contrast to his surroundings.

Probably in wild nature such a contrast is unfavorable to the survival of abnormally colored animals. We have all heard of a white deer, a white seal, or a black gray squirrel, and occasionally one of these oddities may live out its life in spite of being different from its fellows. But generally their enemies can find them more easily, and many animals tend to attack and try to kill even one of their own species that is unusual in any way.

My red toad was retiring at first, but soon learned how good a fat mealworm larva could taste when I put one in front of him. The other inhabitants of my vivarium at that time were a red salamander, who kept hidden all day under the water pan and came out only at dusk to find earthworms, and four baby box turtles, which had hatched in the museum court where I maintained several adult box turtles for many years. Before the toad came, I had been feeding my little turtles on grapes, cantaloupe, tomato, and other soft vegetable food. But from the very second mealworm on, the turtles changed their ideas and became carnivorous hunters. Before the toad could hop over to his mealworm, a turtle was stalking it with outthrust head and menacing eyes. With a peculiar pecking motion of the mouth, almost like that of a fowl, the turtle seized one end of the worm and started to walk off with it. By now the other turtles had realized what was up and were following close behind, the foremost one trying to take a nip at the free end of the mealworm. Before long there were two turtles hanging onto the worm, and then there was a tug-of-war, the worm eventually coming in two in the middle so that each of the contestants won a part. I soon learned to drop five mealworms into the vivarium simultaneously—one in front of each turtle and one in front of the toad. Even then there was sometimes difficulty, for a turtle, not content with his own fat worm, would also seize one from his neighbor's mouth and would try to hide in a corner where he might negotiate them both in peace.

But the turtle did not always get away so easily. The red toad sometimes noticed what was going on and was also attracted by the mealworm's lively wriggling. Then he would hop over to the turtle and with his broad, heavy tongue start to snap at the worm. He also might club the turtle's head in the process, and sometimes succeeded in making the turtle drop the worm, which he then would swallow quickly and efficiently.

While the motion of the toad's tongue—and the frog's too—is too quick to be followed by the naked



eye, it has been well analyzed by the slow-motion camera. The tongue is fastened at the front of the lower jaw, and when the mouth is closed, the tongue tip points backward down the throat. When the toad is about to strike at an insect, the mouth opens and the tongue flaps forward out of the mouth with great speed. As it is sticky, any insect which touches it is carried back into the mouth and there swallowed, by a peculiar process involving the closing of the eyes and the sinking of the eyeballs into the roof of the mouth, which aids the strong tongue to propel the food into the gullet. The protrusion of the tongue is accompanied by a perceptible sound, almost like a gentle snapping of fingers, so that the tongue must act like a small club when it hits the insect.

The American toad, *Bufo americanus* (Plate 38), is rather similar to Fowler's toad in habits and appearance, and occupies part of the same range in the eastern United States. The American toad has its parotoid gland separated from the ridge behind the eye, or connected with it only by a short crest, whereas in Fowler's toad the parotoid gland and the ridge behind the eye lie very close together.

Although inconspicuous when they are in hiding, toads are as a rule rather large for tailless amphibians. Many kinds are between 3 and 4 inches long, while a few—the giants of the genus—are 10 inches long. One of these is *Bufo paracnemis*, the rococo toad, which lives in Brazil, Bolivia, and northern Argentina. A collector in La Paz sent one of this species by airmail to the ethnological division of the National Museum, and since the ethnologists had no use for a live toad, he became mine upon payment of the bill for his postage. In addition to a pair of large bean-shaped parotoid glands behind his eyes, he had another long gland running the full length of the calf of each leg. Only one other kind of toad has these leg glands—the Colorado River toad, *Bufo alvarius*, from the southwestern United States and adjoining Mexico. The lethal qualities of its secreted poison have already been mentioned. I have never attempted to tease my rococo toad up to the point where he might produce a secretion from his protective glands, but I am sure it must be highly effective in protecting him from enemies in the wild state. He is nocturnal and scarcely ever wants to feed by day, even when his favorite food is put in front of him. In summer he stays behind the flowerpots on the floor of my little greenhouse, where he gets a very good living from the isopods and slugs that also hide there, and from the earthworms I bring from the garden to him. He seems to enjoy the fine spray from the hose with which I water the plants. In winter he stays in a



Colorado River toad (*Bufo alvarius*). Lorus and Margery Milne

large vivarium at the museum, because the greenhouse floor becomes too cold for a tropical toad. He has always remained retiring, and will never approach me at feeding time, as many other species of toads have learned to do in captivity. Last year he became mature sexually, the black horny patches that mark the adult male first appearing on his inner fingers at that time.

One of the smallest toads in the world is Rose's toad, *Bufo rosei*, from the mountain slopes above Capetown in South Africa. This tiny amphibian measures just over an inch in length. While it can run at a fairly good speed, it can jump only an inch at each hop. It is a good swimmer, although it has occasion to enter the water only at spawning time. The female produces about 7000 eggs, which are laid in long chains of very tough jelly. The tadpoles reach a length of  $\frac{3}{8}$  inch, a great proportion of this consisting of their long and powerful tails. After about six weeks as larvae, the young metamorphose and leave the water as young toads. At this time, after the absorption of the tail, they are about  $\frac{1}{4}$  inch long, and have been compared to grains of wheat in size. Infant mortality is very high, therefore very few of these may be expected to live to reach adulthood.

Another very small species, measuring  $1\frac{1}{4}$  inches





Oak toad (*Bufo quercicus*). Jack Dermid

at maximum size, is the oak toad, *Bufo quercicus*, found from North Carolina to Florida and Louisiana. It lives in pine woods, hiding under the litter of the forest floor, but is more diurnal than most other kinds of toads. It is beautifully marked, having a creamy yellow or orange stripe down its back and some dark brown or black spots with red-tipped tubercles in their centers. Its voice suggests the peeping of a baby chicken, but when a good many "sing" in chorus, the effect is truly ear-splitting. One of these with his relatively enormous sausage-shaped vocal sac puffed out in front of his face looks like nothing so much as an amusing toy.

The square-marked or leopard toad, *Bufo regularis*, one of the most widely distributed of African amphibians, is encountered literally from Cairo to Cape-

Woodhouse's toad (*Bufo woodhousei*). Lorus and Margery Milne



town, and in Arabia besides. Its sonorous call may be heard from the grassy banks of almost any small pond or stream in the intervening area. The eggs are deposited beginning in August and continuing at least through January, and one pair was known to produce over 24,000 eggs at a single laying. The tadpoles develop rather slowly, and are doubtless preyed upon by water beetles and their larvae, crabs, larval dragonflies, platannas, turtles, and wading birds. The adults are quite secretive except at the mating season, and it is not always easy to find any at other times of the year, so effectively do they hide. They swim well, although they do not have occasion to spend much time in the water after egg-laying is past. Their favorite gait on land is a walk, but if necessary they can jump a considerable distance. Their maximum size is about 5½ inches.

*Bufo empusus* (Plate 31) of Cuba has a bony crest around its eyes. It is nocturnal, and by day digs a narrow hole several inches in depth, in soft earth and at the bottom makes a little horizontal room just big enough for its body. Since it excavates with its hind feet, its head usually remains just below the "chimney," thus blocking it with the heavily boned skull.

Blomberg's toad, *Bufo blombergi* (Plate 32), one of the most spectacular toads because of its great size and handsome coloring, has been known only since 1951. Now nearly every zoo wants one for display, and some are being exported from their native Colombia. The toad grows to a length of 8 inches, and, since it is not timid in captivity, makes an excellent exhibition animal.

*Bufo guttatus* (Plate 33), found in northern South America, is rather like Blomberg's toad in appearance, but is scaled down to 7 inches in size. Unlike most other toads, its skin is nearly smooth, reminding us in this respect of the Colorado River toad, *Bufo alvarius*, of the southwestern United States.

Wiegmann's toad, *Bufo marmoratus* (Plate 37), is a dainty little creature found in parts of Mexico, on both the Atlantic and the Pacific slopes. Its length is at most about 2¾ inches.

The red-spotted toad, *Bufo punctatus* (Plate 36), occurring in the southwestern United States and Mexico, is different from most other species in having round parotoids. These glands are usually oval or elongate, and their shape, while some variation occurs in each species, is of much help in the identification of the toads.

There is a temptation to attribute human reactions to some of these animals. Their bright and lovely eyes look at us with such an appearance of intelligence and friendliness that we tend to forget that



their quota of intelligence, while greater than that of most other amphibians, is still woefully low. As for friendliness, instinct takes its place in the so-called lower vertebrates. It is instinct alone that causes the toads to become gregarious at mating time, to congregate for the all-important act of mating and for laying the eggs that insure the perpetuation of their kind.

Instinct often serves them better than intelligence would. Their instinct to hibernate drives them underground below frost line in those regions where ice and snow cover the ground for a part of each year. Their hiding instinct daily protects them from the many enemies that would quickly make an end to bolder and more conspicuous prey. The efficacy of the toad's complete adaptation to its environment is proved by the present existence of over two hundred species belonging to the genus *Bufo* on all the continents excepting Australia. Neither do they occur on New Zealand, the islands of Polynesia, or Madagascar.

Some other very peculiar genera of bufonids are found in Africa, Asia, the Indo-Australian archipelago, and Australia. Quite unique is *Nectophrynoides*, known from two species found in Africa. Fertilization is internal in this genus, and the females bear their young alive—the only members of the order Salientia that do so. Just how the spermatozoa are

carried to the oviduct is not yet known, and no copulatory organs have been recognized in the male. The developing larvae of *Nectophrynoides vivipara* have very long, slender tails, obviously useless as organs of locomotion in their mother's uterus, and probably respiratory in function, since they are highly vascular. Since there are sometimes over a hundred larvae in a single uterus, none of them can be in contact with the oxygen-giving uterine wall for very long at a time because the bodies of their brothers and sisters constantly crowd them away. The long tails presumably function as pipelines to bring oxygen from the vascular wall to each larva.

Toads that are primarily aquatic belong to the genus *Pseudobufo*, several species of which are found in the Malay Peninsula, Sumatra, and Borneo. They have big webs on the toes, and the nostrils are directed upward, a characteristic of many amphibians that lie at the surface of the water with only their eyes and nostrils projecting. They are rough-skinned and rather large, *Pseudobufo subasper* from Sumatra and the Malay Peninsula attaining a length of 6 inches.

The genus *Nectophryne*, made up of toads that climb trees, is represented by several species in Africa and southern Asia. *Nectophryne hosii*, found in the Malay Peninsula and Borneo, has been known

"False" toad (*Pseudobufo subasper*). M. W. F. Tweedie





to attract attention after dark by the voices of the males as they were clambering about on bushes and small trees. Since they eat ants by choice, tree trunks are a better source of their food supply than the wet, marshy places chosen by most amphibians.

The cricket-voiced toad, *Ansonia grillivoca* (Plate 35), from Balabak in the Philippines, is distinct from true toads of the genus *Bufo* because it lacks parotoids and cranial crests and has very large webs between the toes. All *Ansonias* are small, less than 2½ inches long. They are found in Borneo as well as in the Philippine Islands. The females lay large, non-pigmented eggs in comparatively small clutches of 250 or so. Their larvae have flat bodies, strong, muscular tails, and sucker-like mouths, probably for clinging to rocks in the rapidly moving mountain streams where they live.

## The Mouth-breeding Frog

(Family *Rhinodermatidae*)

The great scientist Charles Darwin discovered the frogs belonging to the single genus and species, *Rhinoderma darwini*, that represents this remarkable family. It is unique in its brooding habits, for a male carries the larvae in an enormously enlarged vocal pouch until the tadpoles are fully transformed. "Mouth breeding" is known in a good many kinds of fish, but this is the only known example of such a

The "vaquero" or Darwin's toad (*Rhinoderma darwini*). Hans Rosenberg



characteristic throughout the whole amphibian order.

The "vaquero," as the Argentinians call it, lives in beech woods of southern Argentina and Chile, where its movements and small size—just over one inch—remind one of a singularly lively cricket. It stands up on its little hind legs before making a short hop forward. The long skin projection on the end of its snout is not its true nose, as the nostrils are well behind it.

The males have small, bell-like voices, but the sacs producing this weak call have a most remarkable function. Several males gather near a clutch of twenty to thirty eggs deposited by a single female. They stay on guard there for ten to twenty days, until the eggs are almost at the hatching point and the embryos are moving inside them. Each of the waiting males then picks up several eggs at a time with his tongue and slides them through the opening at the side of the tongue into the vocal pouch, which is greatly elongated so that it reaches back as far as the groin, turns up over the flanks, and comes forward on the ventral surface until it reaches the chin. Its walls are of the same structure as the lining of the mouth; in fact, the sacs are continuations of the buccal lining. They adhere at intervals to the skin and muscles of the chest and abdomen by connecting tissue. The presence of the larvae in the sac does not interfere with the male's feeding during this time.

Thus the young pass the dangerous larval period in safety in some male's vocal sac—but not necessarily that of their own father! They emerge after completing their metamorphosis, at a length of about ½ inch and with a mere stump of tail left. Although it does not have a free-living period, the larva nevertheless had in the male's vocal pouch all the usual larval characteristics, including a tail, and mouthparts consisting of a scraping beak and labial teeth, although these fail to become hard in the *Rhinoderma* larvae. The pressure upon the male's viscera by the growing young, which may number from five to fifteen, is considerable, for even the direction of his shoulder girdle is changed by their weight. Once they have emerged, however, everything becomes normal again, and the vocal sacs are ready to be used at the next breeding season.

## The Dendrobatids

(Family *Dendrobatidae*)

While nearly all amphibians have at least a trace of poison in their skins, these poison glands are not equally developed in the different families of frogs.



The Bufonidae have a concentration of poison production in the parotoid glands lying behind the eyes, and the secretions of these parotoids are highly distasteful, sometimes even fatal, to the many small mammals that would normally like to prey upon them. The entire skin of the North American pickerel frog, *Rana palustris*, secretes a substance which is lethal to frogs of other species coming into contact with it.

The skin of all frogs contains mucous glands whose secretions serve to lubricate the skin and are also often poisonous to other animals. In addition there are granular glands which emit other poisons for the protection of certain species of frogs. The substance from these granular glands contains more than one poison-producing element; in true toads, for instance, an intensive study has isolated bufotalin, with the chemical formula of  $C_{31}H_{46}O_{10}$ , as well as bufonin, a weaker poison, and bufogin, both with slightly different formulae. The action of these poisons is similar to that of digitalis, since it increases the tonicity of the heart up to the point of stopping the heartbeat, and produces weakened breathing, nausea, and muscular paralysis. A serious inflammation can be caused by toad poisons brought into contact with the eyes of higher vertebrates. While the mucous glands secrete with only the stimulus of dryness, the granular glands require pressure or injury of the toad to cause any appreciable amount of secretion. Sometimes the hands of human collectors of frogs have broken out in a red rash after collecting the West Indian *Hyla vasta* or the African *Phrynomeris bifasciatus*, both of which produce an abundant supply of glandular poison.

The true Borgias among frogs, however, are to be found among the members of the family Dendrobates. "Arrow-poison" frogs were used by the Indians of tropical America to poison their arrow tips long before the coming of the white man. These small but often brightly colored terrestrial frogs belong mostly to the genera *Dendrobates* and *Phyllobates*, found in Central and South American forests. The individuals of some species are very abundant in their home range, indicating that the poison equipment is highly effective in protecting its possessors against the usual hazards of jungle existence.

The Indians kill the arrow-poison frog by piercing it with a sharp stick; then it is held above a fire. The heat causes the skin glands to sweat droplets of poison, which are scraped into a jar and allowed to ferment. The arrows are dipped into this mixture and dried. When shot into the body of a monkey or bird, the poison paralyzes the animal almost instantly, and

so the Indians ensure themselves of food. On larger animals or on man, the poison is ineffective in such small amounts. In parts of South America where these frogs do not occur, arrow poisons are concocted from various kinds of plants.

Most members of the family Dendrobates can be recognized through the presence of a pair of plate-like scutes on the upper side of the end of each finger and toe. One of the most beautiful is *Dendrobates tinctorius*, a small frog having shiny black or maroon skin with large metallic blue spots. Other species may be bright green or pink with dark spots. "Flash colors" are often present in the groin. Their function is uncertain, but possibly they act as a warning to other animals that the frogs are not good to eat, or perhaps they change the appearance of the frog as it makes a leap for safety from its pursuer.

*Dendrobates auratus* from Panama, *D. trivittatus* from Peru to the Amazon, and *D. flavopictus* from Brazil (see Plates 40, 41 and 42), further exemplify the extent of the color range.

In the genus *Dendrobates* a most interesting way of incubating the young has been observed. After the eggs are laid they are attached to the skin of the male's back, and there they eventually hatch, without immersion in water excepting for such showers of rain as may fall on the father in the several weeks during which he is a walking nursery. The young number from two to about twenty, and although their weight is probably negligible even to a frog, their increasing bulk as they grow while clinging stubbornly to his back forces the father to seek larger holes in which he and his little family may remain safe. It is said that, if the tadpoles happen to be dislodged prematurely from the father's back, they are entirely helpless in the water. But at a rather advanced stage they are ready to leave their parent's protection, and when he immerses himself and them in some suitable bit of water, they swim free and enter upon a life of independence. In a year's time they attain their adult size of between 1 and 2 inches, and then are ready to start raising next year's family.

The genus *Phyllobates* is quite closely related, and occupies nearly the same areas in Central and South America as does *Dendrobates*. The former has a half-circle of very small teeth inside the rim of the upper jaw, which can be felt by passing a fine needle around the jaw; the latter lacks teeth entirely. In several species of the genus *Phyllobates* (see Plate 39 of *Phyllobates bicolor* from Peru) the male incubates the tadpoles on his back; just as in the allied *Dendrobates*, and the considerable numbers of specimens of this genus present in every collection from



western South America attest once more to the efficiency of this kind of "baby-sitting."

*Prostherapis*, living in the South American Andes, is like *Phyllobates* except that its toes are webbed. Its poisoning potentialities have not yet been ascertained.

In southeastern Brazil we find a tiny frog that is less than  $\frac{3}{4}$  inch long when fully grown. This is the gold frog, *Brachycephalus ephippium*, a beautiful species with black eyes that look like minute shoe buttons set into its butter-colored head. Its back has a peculiar cross-shaped bony shield, flush with the skin but fused to the underlying neural spines. The function of this shield is not known. Its shape differs a little in different individuals. The gold frog lives on the forest floor among dead leaves, and it is common on the several wooded mountain peaks that rise almost in the heart of the city of Rio de Janeiro.

Another member of this family, also Brazilian, is *Dendrophryniscus brevipollicatus* (with such a jaw-breaking scientific name, it deserves a simple common name), which is not so brightly colored as *Brachycephalus* but is nevertheless attractively marked in velvety brown, tan, and buff. It too lives among debris on the forest floor. In fact, when you pick it up, it stiffens its flat little body and bends backward, so that it looks like a very dry and shriveled leaf rocking in your hand. If you put it back on the ground, it soon comes alive and walks or runs away with a gait rather similar to that of a mouse, not at all like the usual hopping or leaping associated with most tailless amphibians. This odd little creature ranges from the State of Rio de Janeiro through São Paulo and Paraná, Brazil.

The tiny Cuban *Sminthillus limbatus* has the distinction of being perhaps the smallest frog in the world. Its adult length is slightly less than  $\frac{1}{2}$  inch. Each female lays but one egg, since its minute body cavity cannot hold the hundreds, sometimes thousands, laid by most of the larger species. This single egg is, however, large in comparison with the size of the mother. It is deposited in some moist spot on land, and the larva undergoes complete metamorphosis before hatching. The fact that this species is not uncommon indicates that the perpetuation of its kind is not always dependent upon a frog's being able to lay a great number of eggs at each spawning time.

A mountain-top dweller is the small, broad-footed, toadlike *Oreophrynella quelchii*, found only on Mount Roraima in British Guiana. Nothing is yet known of its breeding habits, and in fact only a few preserved specimens have found their way to the museums of the world.

Another rare member of the family is *Geobatrachus walkeri*, inhabiting the high mountains of the Santa Marta Range in Colombia. It lives under leaves and stones and in the axils of air plants.

## The Atelopids

(Family Atelopodidae)

The numerous species of the genus *Atelopus* are found rather widely scattered over most of South America and parts of Central America. Some of these are very odd-looking indeed. The noses are often peculiar, in some kinds the tip of the snout being prolonged into a beaklike affair. Others have squarish heads with snouts that look as if they had been cut off. The feet are often strange too, for sometimes one or two of the inner toes have degenerated or disappeared, while the three outer toes may be more or less fused into a long, claw-shaped appendage. Many kinds walk instead of hop, and never move rapidly. Their coloring is often gorgeous. In Panama there is a large yellow one with black spots that is quite spectacular in appearance. Others have red or green spots on a black background.

*Atelopus stelzneri* from Uruguay is a small, rough-skinned, jet-black toad with bright orange hands and feet. It is famous among herpetologists for the speed with which its eggs develop, the tadpoles emerging a bare twenty-four hours after the eggs are laid. This little toad also has the habit, when suddenly frightened, of bending its head and legs sharply backward over the body, thus turning the lower surfaces of its hands and feet upward so that their gaudily colored skin is exposed. This is presumed to be a warning attitude, as this toad's skin is quite poisonous. The same habit has been noted in members of several other families, among them *Bombina* of Europe and *Dendrophryniscus* of Brazil. At breeding time both sexes (for this is one of the few species in which the female can raise her voice) utter a musical call consisting of two ringing, bell-like notes followed by a descending trill, suggesting the call of a bird rather than of a frog. While bold at other times and slow in movement, this frog becomes intensely active and wary at this time. It swims out to a tuft of grass, climbs upon it, and repeats its call with dilated throat until a female appears. If disturbed, it disappears immediately in the surrounding water. After mating, the female lays her eggs in temporary rain pools. The eggs float on the surface of the water as separate little globes of jelly. After their rapid hatching, the sub-



siding water probably carries the larvae into deeper pools.

The golden-yellow species with black spots from Panama is Zetek's frog, *Atelopus zeteki* (Plate 44). It is diurnal, and in the full sunlight the adults can be seen sitting on rocks in the middle of a stream, where their bright coloring makes them very conspicuous. By night they climb onto plants bordering the stream and sleep on the leaves. They are not at all timid or easily alarmed, and can be caught quite easily, as they neither jump nor swim very well. Their behavior and their abundance suggest that they have few or no natural enemies. No experiments have yet been made to determine if the toxicity of their skins is great enough to give them immunity to the usual dangers that beset frogs. The young ones stay in the woods until fully grown. No breeding call has been recorded, but captive frogs made chirping sounds like the notes made by young turkeys. An adult may measure a little more than 2 inches in length.

Two of the less common species from Ecuador and Peru are *Atelopus Boulengeri* and *Atelopus platanispina*, shown in Plates 43 and 45. They live on the forested slopes of the Andes, the photograph of the latter being taken in cloud forests at an elevation of 3000 feet.

## The Tree Frogs

(Family Hylidae)

Our canoe shot out into the twilight waters of the Severn River in central Maryland and headed for a large clump of cattails on the opposite bank. From the cattails came a very strange noise that sounded as though all the ducks in the county were having a quacking tournament. Yet I knew we should find that the source of the noise was green tree frogs, not ducks.

My companion pointed the canoe into the tall leaves, and all at once the quacking stopped. We sat silently as the sky darkened and stars came out one by one. The soft warmth of a June breeze sent tiny ripples across the water. On the shore fireflies began to rise through the grass, and their little lights flashed in a sort of semaphore. After a few moments we heard an experimental "quack," answered by another at the far end of the cattail patch, and soon the chorus was in full swing once more. I snapped on the flashlight and turned the beam in the direction of the nearest voice.

I saw a handsome green tree frog clinging with disk-



Zetek's frog (*Atelopus zeteki*). A. van den Nieuwenhuizen

like toes to a leaf blade and staring at the light with wide dark eyes that seemed almost to pop from his head. His throat was just deflating from the exertion of his recent call, and I could see the little dusky gray wrinkles under his chin that made him look ridiculously like an old man wearing black goggles.

The light fascinated him, for he did not move as my companion slowly pushed the canoe nearer to him. Now I played the beam on other plants near us, and on nearly all I saw one of these sprawling fellows, while others were in the water. The largest frogs were about 2½ inches in length, but these did not have the gray, wrinkled throat and did not sing, so I knew they were females. The males, who were solely responsible for the din that now was re-echoing all around us, were not over 2 inches long.

Near our canoe we saw a commotion in the water.



A female frog was being courted by three males, and although they did not fight each other as the higher vertebrates are wont to do at mating time, there was a vast amount of elbowing and pushing, as first one male and then another tried to mount the female's back, which is the first step in the external fertilization of the eggs. Finally a male succeeded in achieving the favored position, his forearms clasped tightly around the female's body, his chin pressed closely against her back. Soon a mass of eggs began to issue from her cloaca, and at the same moment the male poured his sperm cells liberally over them. The intimacy of the moment was not respected, for other frogs were now clamoring all about, and this pair was thumped and bumped in no gentle fashion. They seemed not to notice the jostling, and the male did not let go his hold so long as we kept them in view.

The whole riverbank now seethed with creative furor, a mindless obedience to an instinct that insured the continuance of the race. Dozens of mating pairs were briskly depositing their jelly-like egg masses among the cattails. The egg-laying usually was concluded in a short time, when the spent female was released by her mate. I took a few of the fertilized eggs in order to study the various stages until their final metamorphosis into tiny frogs.

The males had now gone on to pursue other females who had not yet deposited eggs. This mating would continue all that night, and perhaps for the next several nights if the temperature and humidity remained favorable. Not all the females were ready to lay eggs at the same hour, but the males would retain their fervor for fertilization until the very last egg had been deposited.

This need to lay eggs in water is one of the chief characteristics that distinguishes frogs as a whole from the next higher order, the reptiles. It links them with the fishes, whose homes and habits are almost entirely aquatic. Even though many frogs can get along on land for most of their lives, nearly all kinds must return to water to mate and lay eggs. It is a hazardous way of life for the tadpoles which hatch from these eggs, for nearly all other creatures want to eat them, including their own big brothers and sisters. To make up for the tremendous mortality among the tadpoles, vast numbers of eggs are laid by a single female. Of each year's laying, perhaps one or two survive to become adult frogs.

I picked up one of the females and put her in a jar, together with a piece of wet sphagnum moss to keep her skin damp during the journey home. Frogs do not drink water—even though they spend so much time in it—but must absorb the necessary body moisture

through their skins; hence they need some degree of dampness at all times. Complete desiccation will cause death very soon, although it is remarkable how unerringly a frog can find the dampest spot in otherwise dry surroundings. Thus I was pretty sure that my frog would not stray far from the plants and the cool sides of the goldfish aquarium in my window. She made herself at home there and soon would accept flies from my fingers without any signs of fear.

She soon demonstrated that frogs are creatures of routine, and follow a daily cycle of movement that was seldom varied. In the morning I usually found her perched on a big begonia leaf; by noon she had plastered herself below the glass rim on the outside of the aquarium (in which she very seldom submerged herself, to my surprise), while late afternoon found her partly hidden in the flowerpot which held a fern. At dusk her activities really began, however, for then she climbed on the window pane, definitely interested in the moths that fluttered on the outside of the window and not understanding why her quick darts toward them were halted by the invisible glass. Sometimes a moth came inside the house, and then there was much leaping and gyrating, much careful stalking when the moth flew beyond immediate reach, and much wild scrambling when the frog's toes slipped on the pane—until at last she had swallowed her dusty mouthful. In calmer moments she liked to have her back gently massaged.

I was interested to find that her color did not change to any appreciable degree during the weeks of her captivity, in spite of the fact that temperature, humidity, and condition of health often cause color changes in some kinds of frogs. She remained a beautiful grass green above, and her underparts were milky white except where tiny blood vessels in the webs between her toes made them look pink when held in the light.

She was not timid as frogs go, and when I approached her window, she would turn her body in my direction—frogs have no movable neck and hence cannot turn the head alone—to wait for the flies and moths that I brought. But autumn came, and I knew that her supply of insects would very soon disappear. The warmth of my living room might perhaps have kept her alert and active even in winter, but with no regular supply of soft-bodied insects to feed upon, she would soon have become emaciated and perhaps would not have long survived. Because she had fed so well during the summer, I felt that her chances of surviving the winter in natural surroundings were excellent. Therefore, one bright October day I carried her to my small back-yard pond and released her on



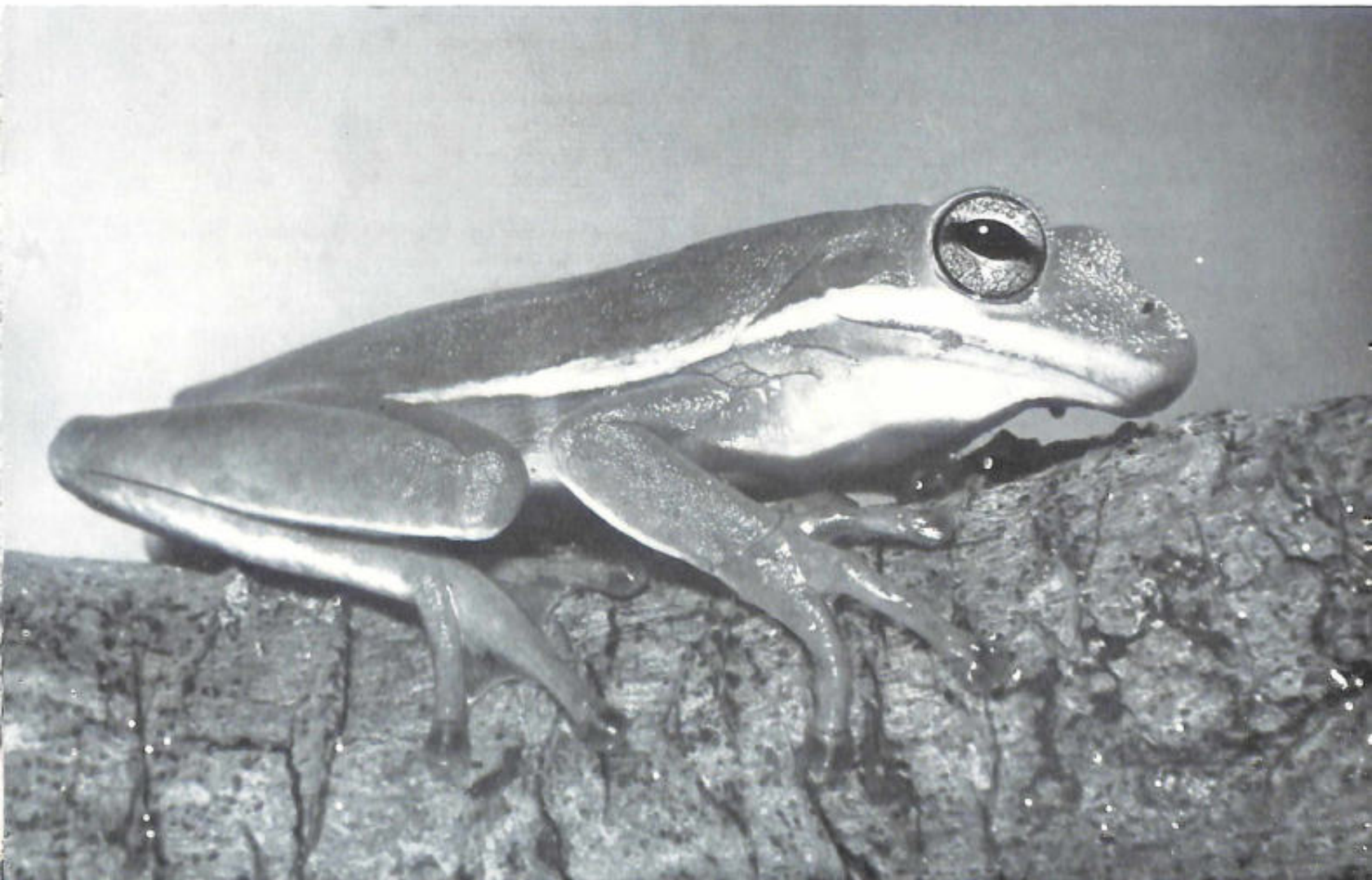
one of the cattail plants that still stood above the water-lily leaves. She promptly hid between the leaf axils, and when I went back to look several hours later, she was still there, apparently content.

A cold spell sent her into the mud at the bottom of my pond, where she spent the long winter. Next spring I caught several glimpses of her among the water plants, but she was no longer tame enough to be approached by anything larger than another frog.

In the meantime, the eggs I had collected had developed according to schedule. While they were still being laid, their gelatinous covering swelled as it came into contact with the river water, until the bulk of the egg mass was several times what it was in the mother's body. Tree frogs usually have no parental interest in their eggs other than selecting a sheet of quiet water in which to lay them, so under natural conditions they are at the mercy of any foraging fishes, salamanders, turtles, or the other fanciers of fresh-laid frog eggs. In my aquarium they had only one enemy—*Saprolegnia*, the fungus mold which often attacks frog and salamander eggs and may spread through them like yeast through bread dough, destroying the whole mass. As it is air-borne, a current

of air may carry it anywhere. Fortunately the eggs I brought home were scarcely affected by the white fungus, and as I was careful to remove any diseased eggs as soon as the mold appeared, the remainder began to develop rapidly. Soon the little black area in the center of each egg had doubled and quadrupled and was well on the way to forming the hollow ball of cells which is the "morula" or mulberry stage of the embryo. Next a long groove appeared on one side of the mulberry, which was to be the spinal column of the baby frog. Soon a little swelling marked the head, and at the opposite end a budlike structure lengthened into a tail. Black eyes on the sides of the head were now discernible, seeming much too large for the tiny body inside the egg envelope. Gills appeared back of the eyes, and then the egg was ready to hatch. Finally the jelly-like egg wall ruptured and a tadpole emerged. It was rather top-heavy, as its relatively enormous head was equipped with oversized gills sticking out on each side. At first it could only hang upright at the surface of the water, not having developed the muscular strength to swim and dive, and not needing to eat because it was still nourished by the egg yolk which hung from its little stomach like a

Green tree frog (*Hyla cinerea*). Russ Kinne





great pouch. This egg yolk lasted several days, by which time the tail muscles had strengthened so that the tadpole could maintain itself in a horizontal position and even make short forays to the part of the aquarium where I had placed a supply of algae.

A tadpole's mouth is a marvelous scraping apparatus. First there is a short, horny beak in the center, not unlike a parrot's in shape but of course almost microscopic in size. On each side of the lips are rows of tiny rasplike teeth—different in arrangement for each kind of frog—which serve as subsidiary scrapers in collecting the minute protozoans and plants that comprise the food of the tadpole at this stage. Tadpoles feed almost continuously and must consume a relatively tremendous amount of this microscopic pap in order to provide for their rapid growth. The greatest difference between the larvae of frogs and those of salamanders is found in the mouth structure. Nearly all frog tadpoles have the lips set with minute, horny rasps arranged in rows above and below the beaklike mandible. When the tadpole begins to metamorphose, its scraping mouthparts gradually evolve into the premaxillary bones and the bones of the lower jaw. But salamander larvae lack these horny teeth and mandibles, being provided almost from the moment of hatching with jaws bearing true teeth. There are some intermediate types of mouth structure, since a few salamander larvae do possess horny plates in their jaws while some tadpoles lack horny rasps.

My green tree frog tadpoles (they belonged to the species *Hyla cinerea*, which is found from Delaware to Florida and westward to Texas) transformed by the end of the summer, when they had reached a length of about an inch. They were very active, and as it would become a problem to secure a sufficient number of gnats to feed them if I continued to keep them, I turned them loose a short distance from where I had taken the eggs.

Tree frogs are the clowns of the amphibian world—acrobatic clowns at that, since they may be seen hanging by one toe from a twig, or pressed flat against a vertical tree trunk, or balanced lightly on a swaying reed beside a river. Barking tree frogs, *Hyla gratiosa*, easily perform on a toy trapeze in captivity. They can do this because the tips of their fingers and toes are expanded into disks that have suction power, permitting the frogs to cling to smooth overhanging surfaces, such as the underside of large leaves, that would certainly present difficulties to any creature not so equipped. They can insert themselves into crevices under the loose bark of trees, or between the leaves of air plants, or into other places where their

enemies cannot readily follow them. Thus they are highly successful in the struggle for survival—a fact attested by the existence of nearly five hundred species of tree frogs. Some occur on every continent, including Australia, and they range from sea level to about 15,000 feet elevation on some of the highest mountains in the world. While most kinds live in the temperate zone or the tropics, some can hibernate through six months of extreme cold in southern Canada. Like all other frogs they require moisture to lubricate their skins, and most of them need quiet stretches of water in which to lay their eggs, but beyond this their wants are few. Insects are plentiful everywhere—or so it seems—and tree frogs are almost entirely insectivorous. They are thus assured of a full meal whenever they care to exert themselves.

It is interesting to see the grace with which a tree frog leaps into the air to catch an insect on the wing. As it rises from the ground, its arms and legs are held in the same plane as its body, thus making a gliding mechanism of the animal's body and ensuring the farthest possible range for its leap. On coming back to earth, the hands and feet spread to secure the greatest amount of contact with the surface on which it comes to rest, while even the skin of the abdomen in some species forms a flat suction disk to hold the frog more firmly in place.

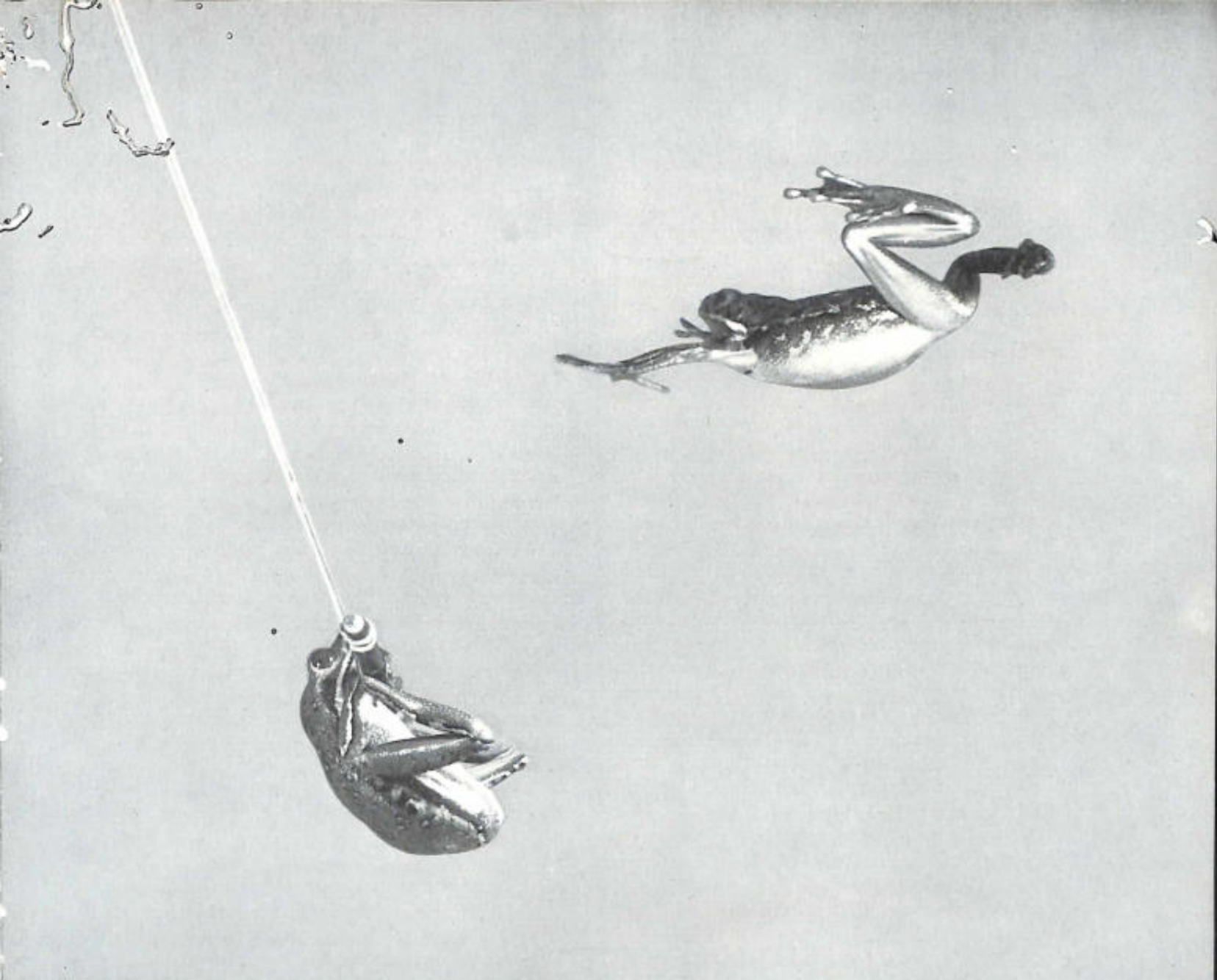
Sometimes as it leaps through the air, some bright-colored spots, usually red, orange, or yellow, are visible, which cannot be seen when the frog is at rest. These are the flash colors, usually located in the groin or on the inner surfaces of the arms and legs.

Like those of toads, the eyes of most tree frogs have a jewel-like quality. They may be golden, wine color, gray, green, or almost any other tint you care to name. Metallic flecks of gold, silver, or copper cross the iris. The skin of the body often has a wax-like or lustrous appearance, and sometimes also a metallic sheen.

As in most other frogs, the skin of the tree frog may darken or lighten depending on the temperature and humidity of the air and the physical condition of the frog. Color cells called chromatophores cause these changes. The expansion of the dark ones (melanophores) causes a gradual darkening of the body tone, while their contraction allows the skin to become light, when the lipophores (yellow-producing cells) or the guanophores (blue-producing cells) are in evidence.

The pattern of the Pacific tree frog, *Hyla regilla* (Plate 52), is subject to great changes in color in a relatively short time as compared to similar changes in most other amphibians. Within ten minutes a deep





Barking tree frog (*Hyla gratiosa*) on trapeze. R. C. Hermes: Annan Photo Features

brown frog without any visible spots may become a pale metallic fawn color with a complicated array of dark spots or short dark bands on its back. The only unchanging feature is the brown stripe through the ear and along the sides of the body.

The spring peeper, *Hyla crucifer* (Plate 58), is one of the earliest of the frogs to appear in spring. Its ringing, metallic chorus, likened to sleigh bells at a distance, can be heard from almost every pond or marshy place over eastern North America to Florida and Texas. In order to produce it, the small singer inflates the vocal sac to enormous proportions, so that it projects far in front of his chest like a balloon. The air going across the vocal chords produces the call, which is immensely magnified in the vocal sac. On

mild evenings of very early spring—in fact once or twice during every winter month in some localities—the chorus may be heard rising from a woodland pond. It has great carrying power, being audible at least a mile away if the wind is right. Its thin, high ringing is the very voice of spring, foretelling the flowering of nature which is to take place at an ever quickening rate with the return of warm weather. If you approach the bank near the pond, all voices suddenly cease at your footsteps, and you might believe that there were no frogs within the entire circle of your vision. But if you stand perfectly still for a few minutes, the very short memories of the frogs lose the image of you as a moving creature and they consider you no more than a tree stump or other fixed object.



You then hear the first trill, and after that the others joining in, some perhaps from right beside your feet. You may see the waxy tan or yellowish body of the little frog, with the brown "X" on the back that gives him his scientific name. As his throat bubbles madly in and out, a slightly larger frog, a female, attracts his notice. She herself is no giant, measuring only about  $1\frac{3}{8}$  inches in length, but she carries eight hundred to a thousand unlaidd eggs. The male ceases his song and hops toward her. With a sudden leap he lands on her back, encircling her body with his forearms. She enters the shallow water and begins to lay her eggs, while he pours the sperm cells over them. The eggs, being sticky, adhere singly to the stems of water plants, where they remain for varying lengths of time, until the increasing temperature of the water causes them to hatch.

The tadpoles are hungry almost from the time of leaving the egg, and go to work with the sharp little rasps on their lips to scratch minute algae and protozoans from the submerged debris in their pool. Metamorphosis is fairly rapid, and in about three months—that is, before the end of summer—the little frogs, no bigger than a fly, are able to leave the pond. Their food at this stage consists of gnats, mosquitoes, and other very small flying insects. To capture a satisfactory meal, which even for such a small frog must consist of dozens of individual insects, the animal has developed a remarkable leaping ability, being able to jump more than seventeen times its own body length. This would correspond to a man's standing broad jump of better than one hundred feet.

The cricket frog, *Acris crepitans* (Plate 57), is an even better jumper, capable of leaping thirty-six times its own length, which is a maximum of  $1\frac{3}{8}$  inches, the same as that of the spring peeper. It is, however, different in appearance from the peeper, having a warty skin, usually green and brown in color, and larger webs between its toes. It has a very shrill, clicking cry, not so musical as that of the peeper but just as penetrating. Sometimes both species sing together in the same pond, as their habit of early emergence from hibernation coincides. But you can usually tell the peepers from the cricket frogs, because the former cling to a cattail stalk or to some little bush at the pond's edge, while the cricket frog climbs only with difficulty because of its different foot structure, preferring to hop along the shore and dive into the water at the least alarm. The cricket frogs, as well as the peepers, have been known to sing during every month of winter from Maryland and Virginia southward, one or two unseasonably warm nights serving to bring them out in full force. Their

calls often last for several hours before the predawn chill drives them back into hibernation.

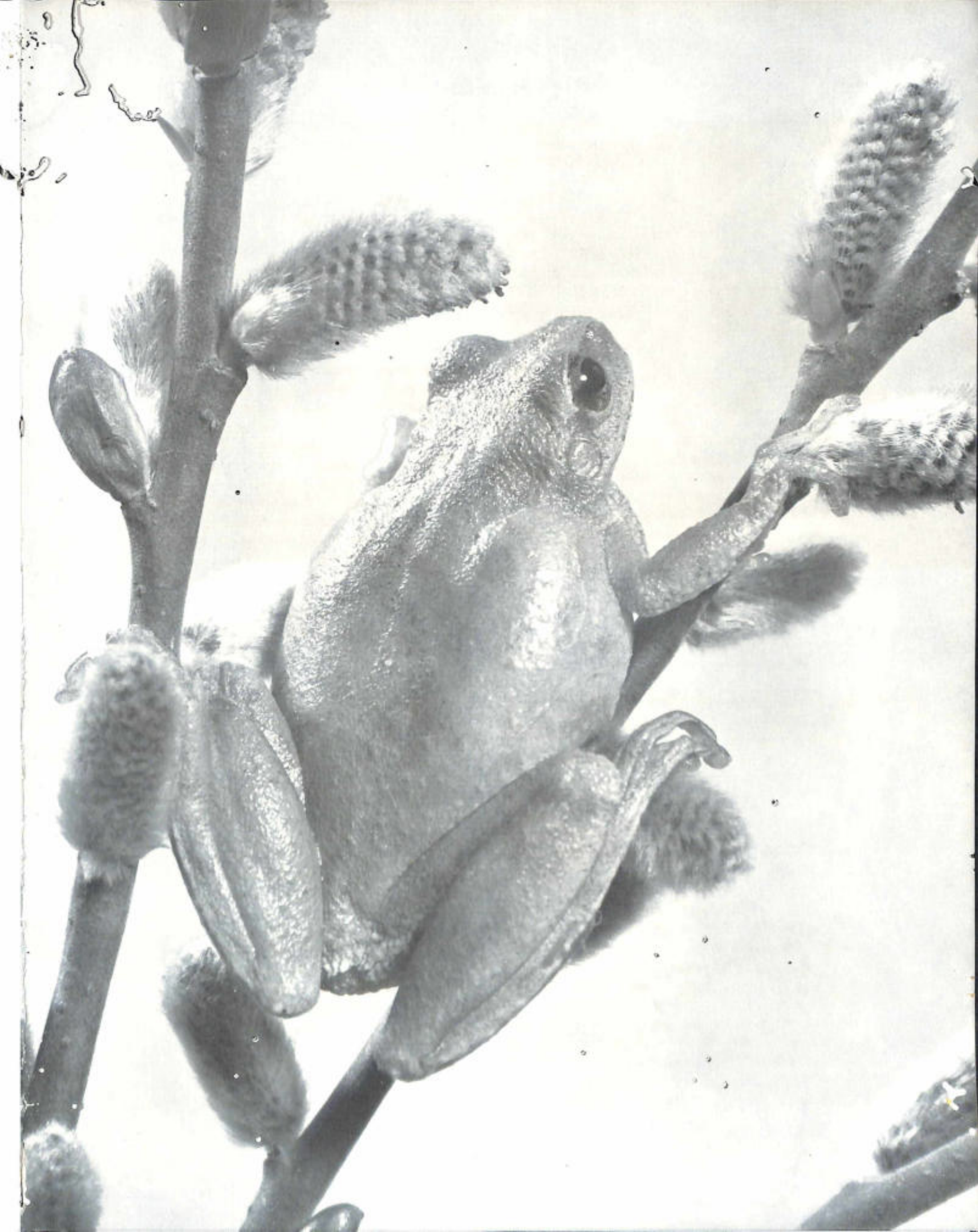
Eggs may be laid as early as February in the southern part of the cricket frog's range, and as late as July in the northern part. When the air temperature is around  $72^{\circ}\text{F.}$ , the eggs hatch in about four days, but if laid when the air is colder, they require a much longer time to hatch. The tadpoles transform between May and October. The metamorphosed froglet may be about  $\frac{1}{2}$  inch in length on leaving the pond some fifty to ninety days after hatching.

At this time their enemies have a field day. In spite of their small size, they are eaten regularly by snakes, fishes, turtles, and a few species of birds, such as the great blue heron and the Florida grackle. The human fisherman finds them to be good bait for the catching of perch. And larger frogs, distinguishing as food only objects that move, snap up a great many cricket frogs with no deliberate intent of being cannibalistic.

The chorus frogs, also called swamp tree frogs, belong to the North American genus *Pseudacris*. They are likewise active in early spring, and their whistling call may often be distinguished in a pond of calling cricket frogs. They are about the same size as the latter—from 1 to  $1\frac{1}{2}$  inches in head and body length—and have similar habits, except that their larger toe disks enable them to climb better among the cattails and low shrubs where they hide by day. The ornate chorus frog, *Pseudacris ornata* (Plate 61), is found along the coastal plain of the United States from North Carolina to Louisiana. Its maximum length is  $1\frac{7}{16}$  inches. Its shrill, metallic call, given as often as eighty times per minute, seems out of all proportion to its tiny body. There are some eleven species in the United States and one in Mexico.

The bony-headed tree frogs are found from Mexico to South America and also in some of the West Indian islands. These frogs are characterized by the possession of a skull that has thickened into a heavy, bony casque on top of the head, with the loose skin that normally covers the head completely fused with this bone. They usually live in tall trees, concealing themselves under loose bark, or in air plants; hence they are seldom seen except by scientific collectors. One that I discovered in a cluster of wild orchids near Niteroi, Brazil, was pure gold in color, except for a narrow brown patch down the center of its back. Its eyes were dull gold, with a peculiar diamond-shaped pupil. It was rather sluggish when I picked it up, and failed to leap and tug wildly for freedom as most newly captured frogs will do. At night, its normal food-getting time, it was a little more active. Its









Pacific tree frog (*Hyla regilla*). Jack Dermid

Bruno's bony-headed frog (*Aparasphenodon brunoi*).  
Senckenberg Museum



cry was a piglike grunting sound. The largest one I ever saw was nearly 3½ inches long. Its name is *Aparasphenodon brunoi*, and it might be called "Bruno's bonyhead" in English.

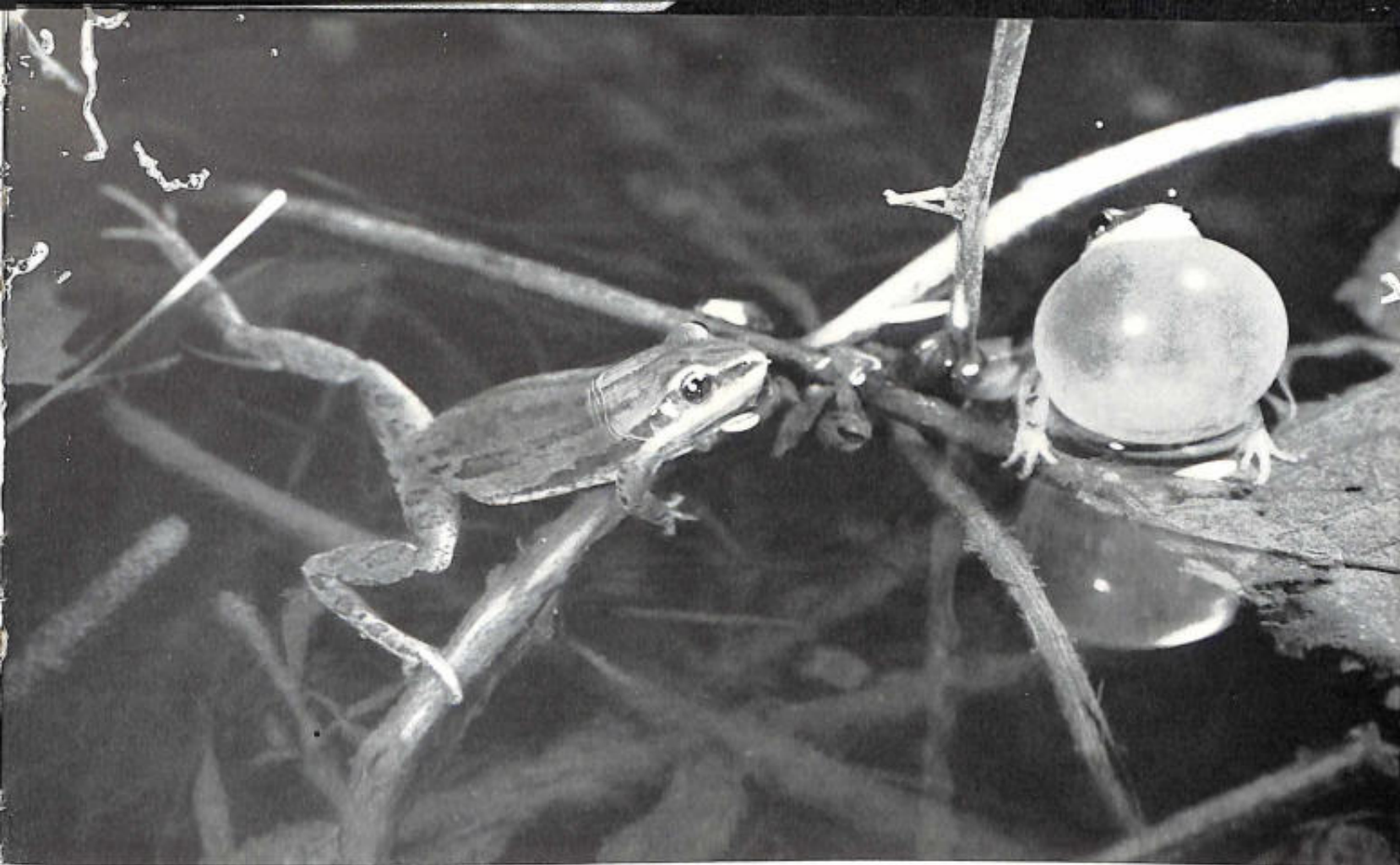
The black-spotted bonyhead, *Trachycephalus nigromaculatus*, is fairly common near Rio de Janeiro, and I had several as pets. Their coloration varies a good deal, some being drab with poppy-red spots outlined in brown; others are buff with large olive black-edged spots. By day this frog hides in air plants or under loose bark in trees, coming out at night to hunt for its insect food. It possesses a good sense of locality, for those allowed the freedom of my laboratory found their way back to their "home" under the lip of the water pitcher at the end of their night's hunting. Their call is a hoarse cawing note that might be rendered as "grau, grau." The males have lateral external vocal sacs that make the head appear very wide when these are inflated.

One rainy evening my Brazilian friends took me night collecting in a florist's garden in Rio de Janeiro. As we walked up a stone path lined with ferns, frog voices came from all around us through the darkness—a symphony of high trills and low booming notes and every sort of sound in between. A small noisy brook dashed down the slope between boulders, and we started down it to look for frogs. Some of the voices came from above our heads, and when we turned our headlamps in that direction, the serrate tips of a banana tree made a bold pattern against the black sky and the wet foliage of other trees around us scattered a thousand little glittering reflections of our lamp—and some of these reflections, we knew, were the eyes of arboreal frogs.

At one side of the stream lay three or four little pools filled with pink and white water lilies wet with rain and gleaming in the light from our torches. The frog chorus, which had been almost deafening, ceased as we came near. A white-banded tree frog, *Hyla albomarginata*, was goggling at us from an orange tree near the pond, with many of its brothers and sisters nearby.

A much larger one, a smith frog, *Hyla faber*, was clinging to a shrub, and I caught it with one hand while waving my light close to its face with the other hand. At the edge of the pool were some nests of the smith frog—surprising bits of architecture a foot across and three or four inches high, made of mud heaped up and hollowed out crater fashion so that the rim came just above the present water level, while the hollow in the center contained a little water and a great mass of frog eggs with very large black centers. We took some of the eggs to be hatched later in our





Southern chorus frog (*Pseudacris nigrita*). John H. Gerard

laboratory. In other pools we saw still more nests which had been constructed when the water was higher, for their edges were well above pond level, and the eggs, now merely moist, were progressing rapidly toward the hatching point. Perhaps this very night's rain would wash them out into the deeper parts of the pool, where the tadpoles would have to dodge the fish and other enemies that would try to eat them. In a little pond barely fifty feet across we counted seven nests, and in one we saw one of the parents sitting, clutching the brim with long, disked toes and fingers. As we walked away the chorus started up again, the strident voices of the smith frogs sounding like someone beating on a tin pan.

Next day in the laboratory our eggs began to hatch, and we had the pleasure of watching the fat, clumsy tadpoles moving around the dish, feeding on algae that we had brought along for them.

I also learned at first hand about the breeding habits of *Flectonotus goeldii*. The female carries her eggs on the center of her back in a basket-shaped hollow surrounded by a rim of translucent skin. She does not produce many eggs at a time—twenty was the greatest number I noted—but her method of ensuring their safety must give them a long life expectancy, for

there was a considerable number of these frogs hunting and hiding among the air plants and under dead leaves in the heavily forested hills in and near Rio de Janeiro. The tadpoles hatch at an advanced stage, when their hind legs have already developed, and the female leaves them in the rain water that collects in the basal leaves of the air plants. In a few more days their metamorphosis is complete and they are ready to set out on life's journey as froglets when less than  $\frac{1}{2}$  inch long. Their meek brown and tan mottled coats are well designed to blend with the low shrubs of the forest floor on which they choose to live. Another egg-carrying tree frog is *Flectonotus fissilis*, also found in Brazil.

One of the largest tree frogs is probably *Hyla maxima* (Plate 62) from northern South America, which grows to a length of  $4\frac{1}{2}$  inches and is related to the smith frog, *Hyla faber*. While frogs as a rule have only four fingers on the hand, this frog has a pollex, or thumb vestige, which appears as a little spur at the base of the inside or "first" finger. It also has folds of skin along the arms and legs that make it seem even larger when it lies flat, and a triangular skin flap on the heel disguises its outline still further.

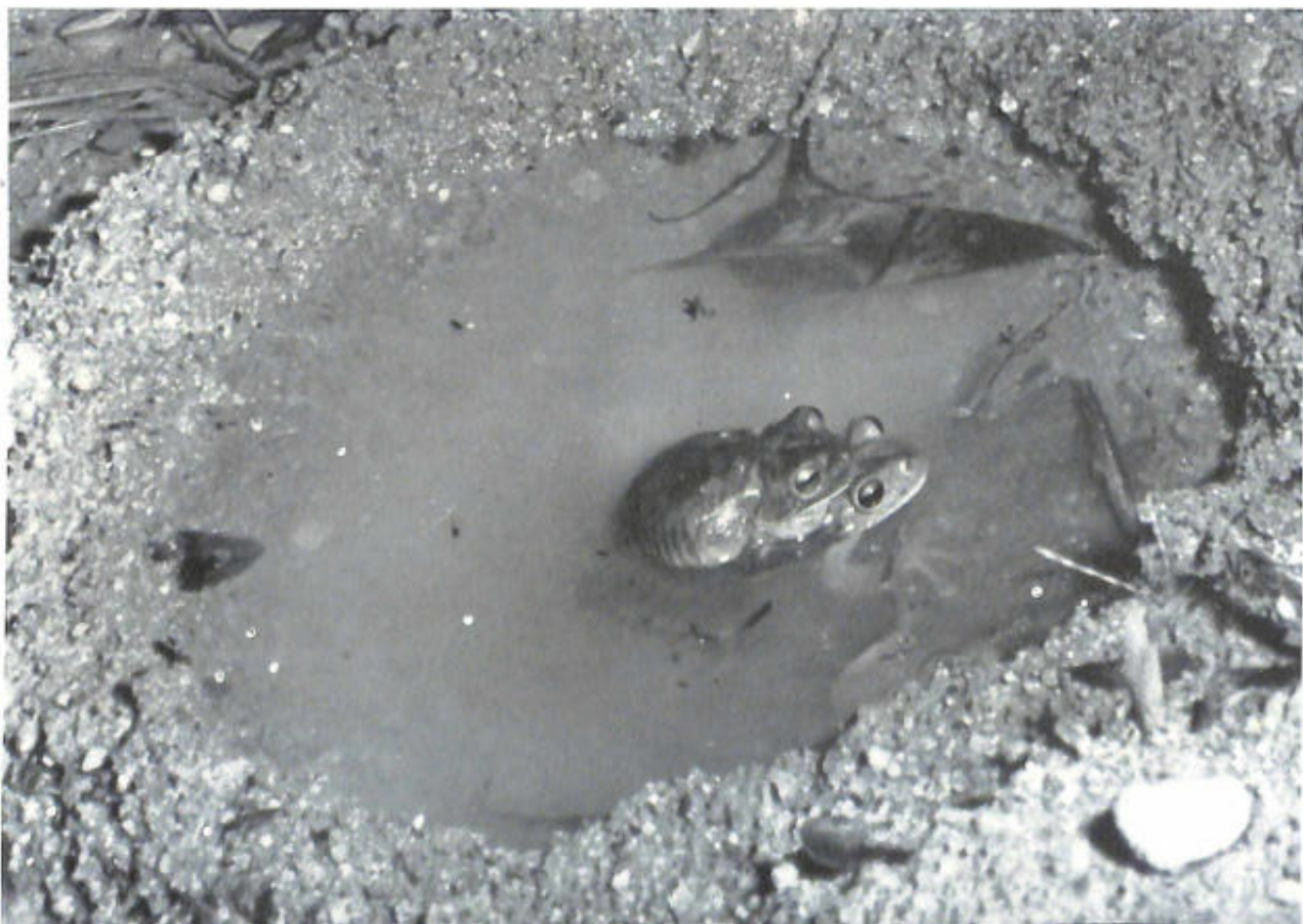
*Hyla vasta* from Hispaniola is another of the





Smith frog (*Hyla faber*), close-up. A. van den Nieuwenhuizen

Smith frog (*Hyla faber*), mating in mud nest. Gualter A. Lutz







Smith frog (*Hyla faber*). Hans Rosenberg



"giants," growing up to 5 inches in length. Its finger and toe disks are very large, looking like round, sticky gumdrops at the end of the digits, and it can cling by the suction of these disks, so that dislodging it is very difficult.

The Cuban tree frog, *Hyla septentrionalis* (Plate 48), is 5½ inches long, but when the legs are extended in leaping it may be close to a foot. This frog has now been introduced from its original home in Cuba and the Bahamas into southeastern Florida and the Keys. It has a very raucous, snoring call, and while there are seldom many of them singing together in one spot, a single male can make plenty of noise by itself. The adults spend much of their time by day in the plants growing on the limbs of tall trees, coming down to standing water on the ground to lay their eggs. They are not timid, and if they happen to live near a human habitation, they are often satisfied to stay inside a flowerpot on the veranda or around the water jars on a terrace.

The smallest tree frog is probably the little grass frog, *Hyla ocularis*, a mite not exceeding 1¼ inch in length, found in the United States from southeastern Virginia to Florida and Alabama. It is especially fond of living in cypress swamps on low plants and on the grassy banks of ponds. Its voice is high in pitch and very shrill. In Florida it breeds all the year round; in the northern parts of its range from January to September.

The gray tree frog, *Hyla versicolor* (Plate 56), is patterned to resemble the lichened bark of the old trees on which it rests during the heat of the day. Its ability to remain absolutely still, except for the vibrations of its throat during breathing, renders its camouflage highly successful. It suggests the bird-voiced tree frog, *Hyla avivoca* (see Plate 60); it is larger, however, and it is found over nearly the whole of the eastern United States, whereas the bird-voiced frog is confined to a much smaller area in the southeastern part of the Mississippi Valley and east to the Savannah River drainage.

The European green tree frog, *Hyla arborea* (Plate 50), is often kept as a pet and as a weather prophet. For the latter purpose, a little ladder is put into its cage, and when it expects fine weather the frog sits at the top of the ladder, while on dark days betokening the approach of rainy weather, it croaks frequently and stays at the bottom of the ladder. Color change in these frogs is considerable, seeming to be due to climatic conditions and also to the emotional excitement of the subject. It is usually bright green on sunny days, but slowly turns to slate color when the sky becomes cloudy. If frightened, the frog also turns





47. Speed might be expected in a treefrog with such a length of leg as Burmeister's frog (*Phyllomedusa burmeisteri*); when disturbed, however, it moves away languidly. (Othmar Danesch)





Cuban tree frog (*Hyla septentrionalis*). Hans Rosenberg

Goeldi's frog (*Flectonotus goeldii*). Richard Oeser



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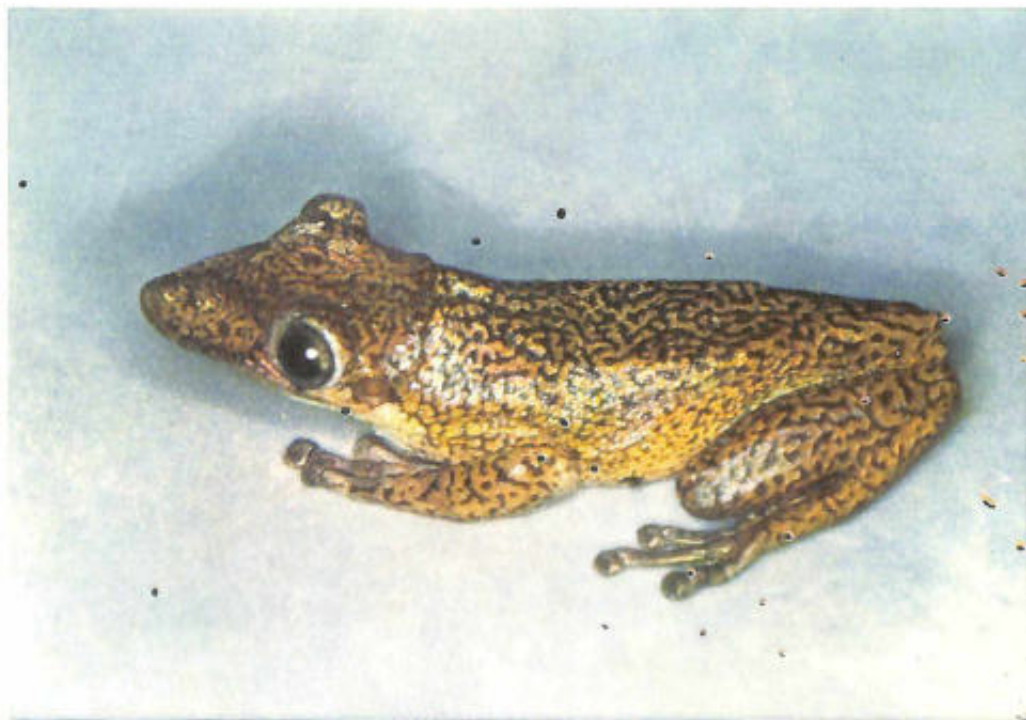


47. Speed might be expected in a treefrog with such a length of leg as Burmeister's frog (*Phyllomedusa burmeisteri*); when disturbed, however, it moves away languidly. (Othmar Danesch)





50. In this picture of the European green treefrog (*Hyla arborea*) the different color phases are well indicated. In 2 or 3 hours, however, the pale one may turn to dark green with changing atmospheric conditions, while the dark one has temporarily turned a pasty buff. (Robert S. Simmons)



51. The Mexican shovel-headed treefrog (*Diaglena reticulata*) is one of the bony-headed frogs. In this one the whole skull has become a casque with a projecting shelf of bone—an over elaborate protection for the minute brain inside. (William E. Duellman)





52. The Pacific treefrog (*Hyla regilla*) like the European green treefrog (Plate 50), also has the ability to change its skin color from a dark brown or green to a light tan in a few minutes. (Robert S. Simmons)



53. The American green treefrog (*Hyla cinerea*) is usually bright green but may turn yellow when calling, or slate-gray when inactive in cool weather. Country folk consider it a weather prophet, since it tends, like the European green treefrog, to sing mostly in rain. (Robert S. Simmons)



54. The red-eyed treefrog (*Agalychnis callidryas*), known from central Mexico to Guatemala and Costa Rica, is one of the few treefrogs with bright red eyes. It is strikingly marked, with a green body, yellow-banded sides, and saffron legs striped with a narrow blue line above. (Harriet Burkhart)



55. In the marsupial frog (*Gastrotheca marsupiata*) the male helps the female place the fertilized eggs in a pouch of loose skin on her back. The edges of the pouch then seal themselves. (John H. Tashjian)







56. The eastern gray treefrog (*Hyla versicolor*) is found from New Brunswick to Florida, and westward to eastern North Dakota and central Texas. Its flutelike call is sometimes heard from a tall tree just before the breeding season. (Robert S. Simmons)



57. A familiar announcement of spring in the eastern and southern United States is the metallic call of the minute cricket frog (*Acris crepitans*), congregating by countless thousands to breed among plant roots in nearly every pond and shallow stream. (Robert S. Simmons)



58. As its popular name indicates, the **spring peeper** (*Hyla crucifer*) is another sign of the glad season. It is often found in the same pools with the cricket frog in the eastern and southern United States, but can climb up on plants and bushes. (Robert S. Simmons)



59. **White's treefrog** (*Hyla caerulea*) is a placid creature, taking well to captivity and sitting quietly for hours between one feeding time and the next. (Erich Sochurek)





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62. The giant treefrog (*Hyla maxima*) may grow to a little over 4½ inches in length. Not many are captured for zoos, as they live in heavy jungle in northern South America. (James N. Layne)

61. The ornate chorus frog (*Pseudacris ornata*) is less than 1½ inches long when full grown. It lives in cypress ponds or flatwoods ditches along the coastal plain from North Carolina to Louisiana. (Robert S. Simmons)

60. The bird-voiced treefrog (*Hyla avicoca*) occurring from the eastern Mississippi Valley to the Savannah drainage, suggests the gray treefrog in appearance, but is smaller, and has the concealed parts of the legs green instead of orange. (Robert S. Simmons)







63. In its search for insects, the leopard frog, also called the meadow frog (*Rana pipiens*), hops about in grassy fields often some distance away from water. In its vast range—much of North America—are found certain color patterns that cause some scientists to believe that several different races are represented. (Robert S. Simmons)







64. One of the commonest frogs throughout its wide range from southern Canada to North Carolina and Oklahoma; the green frog (*Rana melanota*) may be heard from April to August sounding a single call note like the plucking of a cello string. (Wilfred J. Lachapelle)





65. Earliest of the North American frogs to come out of hibernation, the **wood frog** (*Rana sylvatica*) frequents shallow woodland pools. Its "robber's mask" resembles that of the European *Rana temporaria*. (Robert S. Simmons)



66. The **pickerel frog** (*Rana palustris*) has a brassy hue emphasized by a row of nearly square brown spots along each side of the back. It lives in southern Canada and in much of the United States east of the Rockies. (Robert S. Simmons)





67. Boulenger's platymantis (*Platymantis boulengeri*) comes from New Britain in New Guinea. Unlike the typical *Rana* it has the toe webs much reduced. It lays large, colorless eggs probably out of water, and its larvae apparently skip the free-swimming stage. (E. Thomas Gilliard)

68. The golden mantella (*Mantella aurantiaca*), living in wet forests of Madagascar, was long thought to be related to the tropical American Dendrobatidae. Recent study, however, has established it as a member of the Ranidae. (Erich Sochurek)



69. Although it has been known for over a century from Gaboon, and was recently found in the Belgian Congo, no observations have been published on the life history of the West African brown frog (*Rana subsigillata*). It presumably follows the family pattern in breeding and development. (R. F. Laurent)





70. Hose's frog (*Rana hosii*) from Borneo, Sumatra and Java is a handsome 4-inch frog, that can make an enormous leap with its long, muscular legs, and swim rapidly away once it has reached water. (Robert F. Inger: Chicago Natural History Museum)

71. The silver-striped sedgefrog (*Hyperolius argentovittis*) from Tanganyika belongs to a genus most variable in color and pattern. This little fellow, only an inch long, has a complex pattern that renders him invisible in his native grasslands. (Hy Marx)







72. The tiny **five-lined sedgefrog** (*Hyperolius quinquevittatus*) is only slightly over an inch in length when full grown. It inhabits Angola and the Congo basin as far as Tanganyika. The strong, striped pattern of the male is seldom seen in the female. (G. F. de Witte; Institut des Parcs Nationaux du Congo Belge)



73. The **bony-headed rhacophorus** (*Rhacophorus ottilophus*) from Borneo has a bony head like some of the Hylidae. The region between the eyes is here roofed over by bone, while a spiny crest caps the upper ear drum, and a spine marks the angle of the jaws. (D. Dwight Davis; Chicago Natural History Museum)



74. The **sheep frog** (*Hypoparlaus cuneus*) remains in burrows to escape the heat and drought of its native regions in southern Texas and central Mexico. When rain comes, it times its breeding to coincide with the formation of pools. (Robert S. Simmons)



75. The spotted hylambates (*Hylambates maculatus*), known from Mozambique to Zanzibar, has been familiar to scientists for more than a century. In captivity it does very well on a diet of moths. (Constance P. Warner)







76. Like the dozen other members of its genus, the Cape short-head (*Breviceps gibbosus*) usually lives in termite nests in the Cape Peninsula of Africa. (Edward S. Ross and *National Geographic*)



77. The South African short-head (*Breviceps adspersus*) is a flat-faced little beast about 2 inches long with a warty skin. It spends almost its entire life underground. (Edward S. Ross and *National Geographic*)



[ continued from page 120 ]

bright green, but since it soon becomes accustomed to captivity, the occasions when a captive's color change results from fright become fewer and fewer, and its value as a weather prophet is thought by some to increase accordingly. A southern relative is the Mediterranean treefrog, *Hyla meridionalis*, from the Canary Islands and Madeira as well as the borders of the Mediterranean.

As I have said before, there are not enough common names to go round. *Hyla annectans* of western China is also called the green tree frog, as are the North American *Hyla cinerea* (Plate 53) and the European *Hyla arborea* mentioned above. *Hyla annectans* hides by day, emerging at dusk and uttering its sharp, high call note. It breeds from April through June in ponds, flooded rice paddies, and wherever there is standing water. It is easy to catch at breeding season by dazzling it with a flashlight, but at other seasons it is hard to find, because it is adept at concealment. At Yenyuan City this frog is known as the "bamboo spirit," since it calls from bamboo clumps while remaining invisible, and the natives have never succeeded in tracking a voice to its owner. In Sze-anhung it is called the "mulberry spirit" when discovered in holes in old mulberry trees. It was formerly considered a very valuable medicine when found in mulberries, and was presented to the Emperor as a prized gift during the Tsing Dynasty.

One of the best known of the Australian hylids is

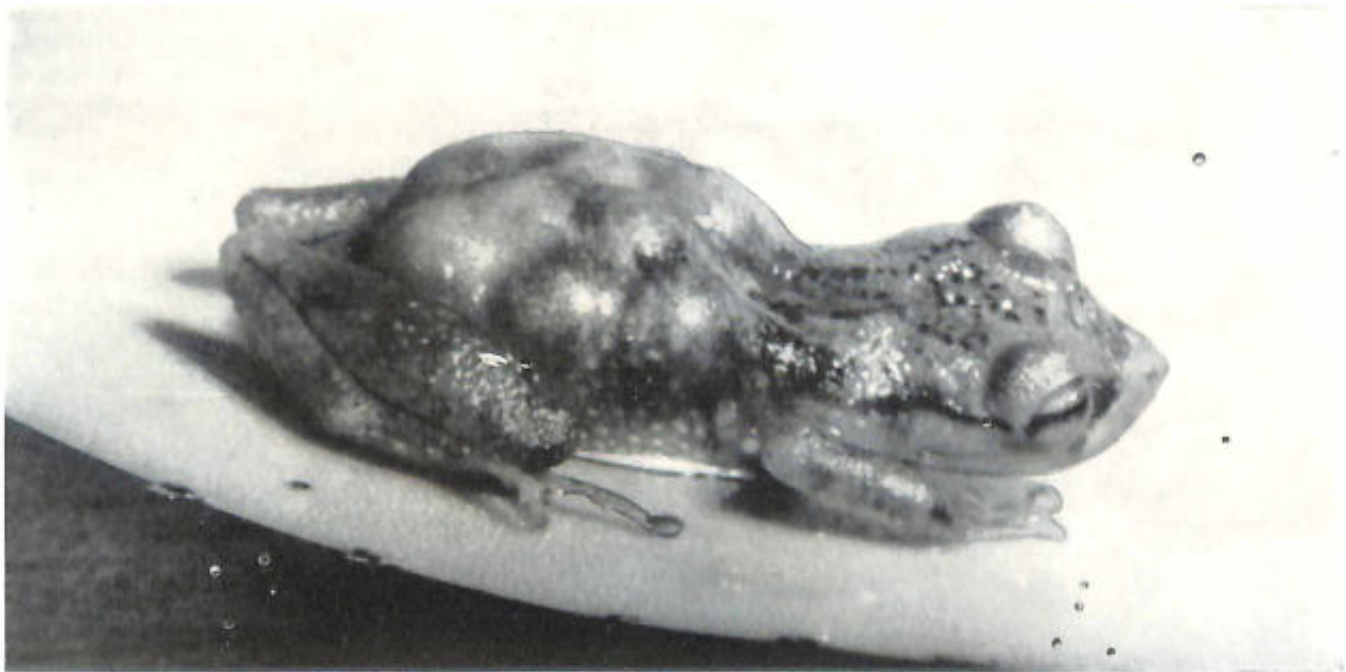
the golden tree frog, *Hyla aurea*. It is more aquatic than the other Australian tree frogs, staying in the water or on low vegetation nearby. Its finger and toe disks are quite small and are not very useful for climbing. Breeding begins in spring and continues throughout the summer. The call of the male is said to resemble the mallet and chisel sounds made by a number of stonemasons plying their trade. Some people also liken the call to the distant sound of cowbells.

The eggs are laid in masses that are usually entangled among stems of water plants at the bottom of the pond. The adult grows to a length of more than 3 inches. Its popular name refers to a handsome golden or bronze stripe along the sides, while its back is emerald green to bluish green. It is a fat, round frog that tames easily, and one was known to live more than fifteen years in captivity. Its favorite foods seem to be earthworms and smaller frogs.

White's tree frog, *Hyla caerulea* (Plate 59), also Australian, has almost "domesticated" itself in its native clime, for it is said to come frequently to verandas and even inside houses on summer evenings. It makes a very handsome pet, especially as its shiny green skin makes it look like a wax figurine. In captivity it readily takes its quota of insects from one's fingers.

Although I have called *Hyla infrafrenata* the New Guinea treefrog, it is actually found from Java to

Split-backed frog (*Flectonotus fissilis*). Gualter A. Lutz







Giant tree frog (*Hyla maxima*). Russ Kinne



Queensland. The rattle-voiced treefrog of South America, *Hyla crepitans*, is well described by its Latin name.

One of the less familiar Australian frogs is *Hyla genolanensis* (Plate 46). It seems remarkable that such a small, delicate creature, so dependent upon water for its existence, should be able to live successfully in regions subject to intense and often long droughts. We find some twenty-one species of *Hyla* in Australia, and another fifty or so are known in the East Indies. Not much has been recorded as to their habits and life histories. Including the New World forms, there are nearly four hundred species of frogs belonging to the genus *Hyla*.

The South American *Phyllomedusa burmeisteri* (Plate 47) is a slow, deliberate creature when forced to move in the daylight. Even by night, when its cat-like pupils give it great seeing ability, the heavy hand-over-foot crawl along a small branch does not suggest its close relationship with the almost frenetically active *Hylas*.

*Phyllomedusa appendiculata* (Plate 49) takes its scientific name from the skin flap or appendage on the heel, presumably useful in disguising its outline when it is resting on a tree trunk.

Rohde's treefrog, *Phyllomedusa rohdei*, insures the safety of its eggs by glueing them to a leaf overhanging a pond. When the eggs have developed to the early tadpole stage, the larvae drop into the water and remain there until they have metamorphosed into young froglets.

*Agalychnis callidryas* (Plate 54) has startling red eyes with vertical pupils, the color emphasized by its brilliant green back and creamy sides and underparts. It is found from central Mexico to Guatemala.

A genus of tree frogs, *Gastrotheca*, called the marsupial frogs, has a true dermal pouch for the eggs, which are quite numerous, and which cause the female's dorsal region to appear very swollen in the last stages before hatching. The scientist who named this genus in 1843 evidently confused the position of the pouch, for "gastrotheca" means literally "stomach

White's tree frog (*Hyla caerulea*). A. van den Nieuwenhuizen





pouch," while these frogs have the pouch definitely confined to the back. The hatching of some young *Gastrotheca marsupiata* (Plate 55) has recently been observed. At the time of their emergence, the female raised a toe of her hind foot to her back and pulled apart the slitlike opening of the pouch, so that the young, which were very fragile and delicate, could escape.

*Diaglena reticulata* (Plate 51) is a bony-headed frog in which the skin and the top of the skull have become completely fused. It was discovered in Oaxaca, Mexico, in 1942, and its life history has not yet been fully studied.

## The Centrolenids

(Family Centrolenidae)

In Central and South America lives a group of small green or yellowish frogs having a single fused tarsal bone instead of two such bones, as nearly all other frogs have. This and some other unusual characteristics allow them to be put together into the family Centrolenidae. Because of their somewhat similar outward appearance and habits they used to be considered Hylidae, but more careful study has brought their acceptance as a distinct family.

Most of the centrolenids have wide, blunt heads and rather small eyes set almost on the upper surface of the skull. They are arboreal, living on the leaves of small trees and shrubs, and usually close to running water. Most kinds are small in size, from  $\frac{3}{4}$  to  $2\frac{1}{4}$  inches in length. In some species the males have a peculiar bony hook on the upper arm just in front of the shoulder. In females this hook is either internal or wholly absent. What the function of the hook may be, and why all members of the family do not have it, remain among the many unsolved problems that plague the naturalist.

The eggs are laid on leaves above water, and as soon as they have hatched the young tumble down into the water for the completion of their tadpole stage.

While most frogs that are green in life turn to slate-gray or brownish in preservative, the centrolenids assume a dark reddish or purplish tinge after they have been fixed in alcohol. Every chromatophore is outlined in purple, and these color cells are seen to be concentrated in dark stripes down the upper surfaces of the arms and legs, as well as heavily on the back and head. The eyeballs become opaque silvery white, looking like large pearls with a thin purple veil of upper eyelid over them.

In life, the skin and flesh of the ventral surfaces are nearly transparent, allowing the viscera to be seen fairly well through the abdominal wall. After killing,

Mediterranean tree frog (*Hyla meridionalis*). Othmar Stemmler







Riobama pouched frog (*Gastrotheca riobambae*). Edward S. Ross

Rattle-voiced tree frog (*Hyla crepitans*). Russ Kinne









much of this translucence remains, as there are scarcely any pigment cells on the belly of the frog to conceal the visceral content.

Members of this family are known from Veracruz and Guerrero in Mexico to Colombia, Ecuador, and Brazil.

One day I went on a collecting trip near Petropolis, which is in the mountains about two hours by train from Rio de Janeiro. At the outskirts of the town there is a fine waterfall that descends with a loud roar through a chasm lined with giant trailing begonias, purple quaresma trees, and white arum lilies. As I climbed the side of the gorge, I found many kinds of frogs—some hiding under stones, others asleep in leaf axils or plastered flat against the spray-drenched rocks. Some were a lovely jade green that matched the leaves on which they rested, and had silvery eyes that followed my every movement. They usually leaped away just as I was about to lay my hand over them. Finally I got one about an inch long, which later turned out to be a new species,

*Cochranella petropolitana*. Another new one just a trifle larger was also taken there that day, making the trip amply worth while.

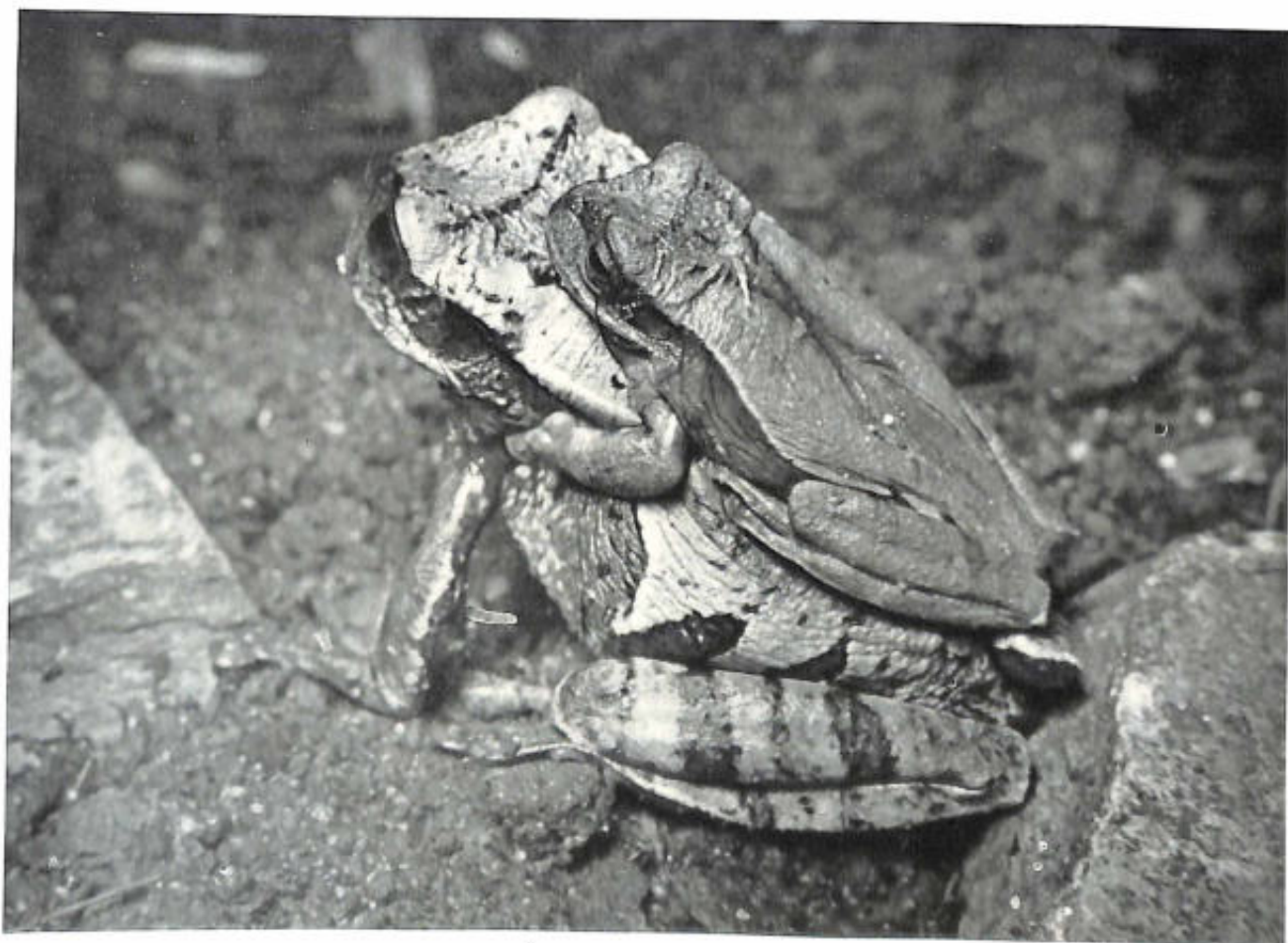
## The Heleophrynids

(Family Heleophrynidae)

This family contains some rare South African frogs that were once combined with the Bufonidae, the Leptodactylidae, and the Ranidae in turn. Its members have teeth on the vomer, while the Bufonidae lack teeth. Other anatomical differences bar it just as effectively from the Leptodactylidae and Ranidae.

Members of the several species belonging to its sole genus, *Heleophryne*, are seldom encountered, even in the areas that they are known to inhabit. Their tadpoles can usually be discovered in swift mountain streams, but once the larvae have trans-

Pouched frog (*Gastrotheca ovifera*). Senckenberg Museum



Gray tree frog (*Hyla versicolor*). Jack Dermid







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Pouched frog (*Gastrotheca ovifera*). Senckenberg Museum



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Rohde's leaf frog (*Phyllomedusa rohdei*) showing mating and (at right) eggs secured to a leaf. M. Van Rekum

Marsupial frog (*Gastrotheca marsupiata*). Wilhelm Hoppe





formed and come out on land, they are very hard to track down to their hiding places.

The first species to be made known to the world was *Heleophryne regis*, described in 1899 from Stellenbosch. Since then, three species have been found. One of the best known is the so-called "ghost frog," *Heleophryne rosei*, from Table Mountain near Cape-town. Its unusual tadpoles were first observed in mountain brooks, and as it was realized that they were unlike any larvae of known species from that region, careful searching finally revealed a few adults.

While aquatic larvae of most frogs are more or less round or egg-shaped, the ghost frog tadpole has a flattened head and a wedge-shaped outline when seen from above. The enormous suction disk around its mouth enables it to cling tightly to the surfaces of submerged rocks, while it browses slowly on the algal growth, the grip of the sucker being shifted slightly as the small scraping teeth detach the microscopic plant and animal food on which the little creature nourishes itself.

The adult ghost frog is about 2½ inches in length, green above with a reddish network pattern, and the white skin below is so thin that it permits the abdominal viscera to be seen. In spite of its disked toes and fingers, it apparently does not lead an arboreal existence, but instead is content to crouch in a hole or under a stone, and frequently takes to the water. The shed skin floats away in pieces, the frog making no attempt to rid itself of the fragments or to swallow them when shed, as the members of most other frog genera do. In the adult, the skin has small hooks, quite visible to the naked eye, in regular patches along the lower surfaces of the forelimbs and on top of the fingers. Other similar hooks appear in a double row along the lower jaws, while a few others are scattered over the nose and upper jaw. On the legs, only scattered granules occur. The hooks are believed to aid the frog in climbing over slippery rocks.

Another peculiarity of the ghost frog is its diamond-shaped pupil, of which the longer axis is vertical, not horizontal as in most other frogs.

One of its relatives, *Heleophryne purcelli*, lacks the tiny hooks on the skin, but instead has sharp, spiny tubercles. It is partly arboreal, and leaps after flies.

The breeding habits of these frogs are not yet completely known, although dissection of a mature female ghost frog disclosed about thirty yellowish eggs of rather large size, which might later have been laid in a hole in the riverbank above water.



Marsupial frog (*Gastrotheca marsupiata*), Wilhelm Hoppe





New Guinea tree frog (*Hyla infrafrenata*). Senckenberg Museum



Ghost frog (*Heleophryne rosei*). Walter Rose



## The Pseudids (Family Pseudidae)

The genus *Pseudis* has long puzzled zoologists because of its structural peculiarities, and it has been shifted from one family to another. Since it has no very close relatives among any of the other frogs, it was recently suggested that a separate family be made for it.

The frogs of this genus are lively creatures whose light-yellow-and-black striped legs suggest a harlequin version of a gentleman in a cutaway coat and pin-striped trousers. Their skin is extraordinarily slippery to the touch; hence they can elude an enemy snake or fish that fails to get a firm grip on them at the first strike. Among dark and light stems of floating water weeds they are nearly invisible, for only their bulging eyes and nostrils appear above water; and since they are very easily frightened, they dive to safety in the deep mud at the merest suggestion of danger.

Their long and slender toes and fingers each have an added phalanx, which may give more mobility to their digits. They use it in stirring up mud to find their food at the bottom of the shallow lakes where they live. In addition, the thumb is opposable to the other fingers, a condition not often found in frogs. They are noteworthy for another peculiarity: the tadpole grows monstrously, achieving a bulk several times that of the adult it may soon become, so that in its metamorphosis a definite shrinkage of the body organs—instead of the expansion normal in most frogs—takes place. The natives take advantage of their large size, catching the fat tadpoles as well as the adults on hooks baited with grasshoppers and selling them as appetizing tidbits in local markets.

The largest and best known species is *Pseudis paradoxa*, called paradoxical because of the very disproportion between the larva and the adult. Early scientists found it hard to believe that such a huge tadpole—one is recorded as measuring over 10 inches—would or could metamorphose into a moderate-sized frog only 3 inches in length. The larva, therefore, received several scientific names in its own right, a thing that often happens when an immature form is so misleadingly unlike what it turns into eventually. All these names after the first one were, of course, invalidated as soon as the true life history of the frog and its remarkable changes of form were recorded. Entirely aquatic, it lives on the island of Trinidad and in the Amazon River system of northern South America.

←  
Paradoxical frog (*Pseudis paradoxa*).  
New York Zoological Society



Almost a hundred years ago a very rare species, *Pseudis fusca*, was collected in the Rio Arassuahy in Bahia, Brazil. Only two or three individuals were taken at that time and none has been captured since then. An allied species, *Pseudis bolbodactyla*, was discovered more recently only 150 miles away but on a different watershed and separated by high mountains that would effectually prevent the two species from mingling and possibly hybridizing.

One hot, bright afternoon in Minas Gerais, my companions and I set out for the shallow lake which was the type locality of *Pseudis bolbodactyla*. On our way we came to one of the tributaries to the Rio São Francisco, in itself no small stream. Moored on our side of the river were some dugout canoes, each hollowed from a single log in the traditional fashion. Some natives approached with the intention of crossing to the other side, but stopped to make obeisance to the river gods and mutter the proper spells before untying their canoes and setting out on the water.

A little farther upstream we turned toward a swampy area and soon found ourselves at the lake—a smooth, gleaming sheet of water several miles

broad, but nowhere more than two or three feet in depth. It was a heaven for dragonflies and their numerous kin, which delight in laying eggs in such a situation. I knew that the floating clumps of water plants also harbored the frogs we sought, for I could hear the coughing grunt, almost like that of a pig, which is their "song." Wading in up to my knees, I could see all around me the upturned faces of the frogs, but try as I might to catch hold of them, they slipped through my hands like water. Finally I had the idea of using my large metal forceps, which had slightly roughened tips, and with these I soon grasped and held my first live *Pseudis*. When my pail contained a dozen or so of the adult frogs, and some of their huge tadpoles, which were easier to capture in a dipnet, I took them back to the laboratory to watch them and to make my color notes. They were indeed graceful when viewed through the aquarium glass, as they seemed to bow and curtsy to each other like dancers in a masquerade party while fanning their delicate fingers continually through the water. A few strips of shredded beef dropped into the tank put an end to all formality, however, and from that moment until the meat

Paradoxical frog (*Pseudis paradoxa*). Lorus J. Milne

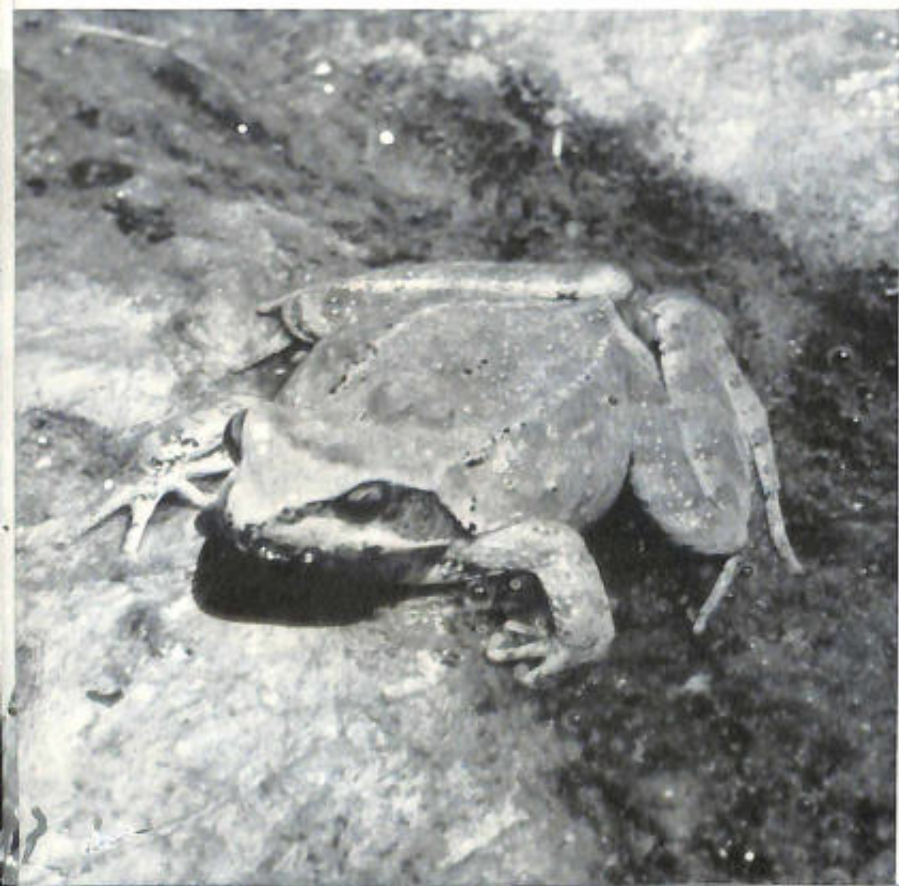






Wolterstorff's frog (*Rana wolterstorffi*). Othmar Stemmler

Grecian frog (*Rana graeca*). Othmar Stemmler



was gone, it became a free-for-all to see who could push away his companions while grabbing the choicest pieces for himself. The adult of this species measures a little less than 2 inches in length when full grown, and its tadpole is correspondingly less bulky than that of the larger paradoxical frog. Some very small species from the Paraguay River are less than an inch in length.

## The True Frogs

(Family *Ranidae*)

As our language is singularly poor in common names for the eighteen families of tailless amphibians, "frogs" and "toads" are the only English names in popular use for about 2600 different species of these creatures. The name "frog" is correctly applied only to members of the genus *Rana* and its close allies, just as "toad" is properly used only for the genus *Bufo* and near relatives. But we qualify these names for some of the other families—"tree frogs" for Hylidae, "narrow-mouthed toads" for Microhylidae, and so on. Nevertheless, we use the names "frog" and "toad" for many animals that are not really related closely to either of these amphibians.

True frogs of the genus *Rana* are found all over North America; in Central America and in the northern part of South America; in all of Europe, Asia, and Africa excepting frozen or desert areas; and in northern Australia, but not in southern Australia or New Zealand. Perez's frog, *Rana perezii*, from southern Europe; and Wolterstorff's frog, *Rana wolterstorffi*, and the Grecian frog, *Rana graeca*, both from the Balkans, are good examples of the true frogs. Most frogs are streamlined, with bullet-shaped bodies and pointed heads, large eardrums, protruding eyes, long, webbed toes, and well-developed legs that enable them to make prodigious leaps when escaping from danger. They live in swampy areas or in shallow lakes, although some may travel quite a distance inland through the grassy fields in their never ending search for insect food. Some of the larger kinds, such as the common bullfrog, *Rana catesbeiana*, found in the United States east of the Rockies, may devour young water birds, ducklings, swallows that dip too close to the frog's eager leap, young turtles, the less speedy fish, and their own younger brothers and sisters.

Frogs have unwittingly done much to help man in his educational or scientific activities. It was the exposed nerve in the dissected leg of a dead frog which



resulted in experiments for the transmission of electric current by Galvani, the pioneer in the study of electrical impulses. Frogs are also a basic part of biology instruction. Every teacher of zoology uses preserved frogs to demonstrate anatomical structure. Frogs are usually easy to obtain, and their different systems—alimentary, nervous, circulatory, reproductive—can be traced with such readiness that they constitute one of the best laboratory subjects for comparative anatomy. Medically, the live frog is of use to the gynecologist, since human pregnancy can be tested by injecting urine from a supposedly pregnant woman into a female frog, as described earlier.

Much has been discovered about limb regeneration by studying the larval and metamorphosing frog. It has long been known that a metamorphosing froglet which loses an arm or leg to some hungry fish or other enemy will quickly regrow the limb. But after the frog has completely metamorphosed and has taken on the fully developed form of the adult, a lost arm or leg will not be replaced. A great deal of work has

been done in transplanting tissues on metamorphosing frogs. Students of medicine have found that not only patches of skin but even limbs, eyes, and body organs can be transferred from one frog to another, in most instances with complete success, and young frogs with an extra transplanted arm or heart have been reared to maturity after the operation. Study of this technique is still going on, and with constant improvement it may one day lead to the possibility of restoring an arm or a leg in a human being.

We owe to frogs still another debt—that of our enjoyment of their flesh. Frogs' legs are a gourmet's dish served at the finer restaurants the world over. A host of other animals like dining on frogs—small mammals on riverbanks in all parts of the world, big fish, wading and diving birds, aquatic turtles, water snakes, and not least of all, their own elder brothers and sisters, who strike at moving food and fail to distinguish between a young froglet of their own breed and a luscious insect.

But in spite of so many casualties, the frog popula-

Perez's frog (*Rana perezii*). Gerhard Budich

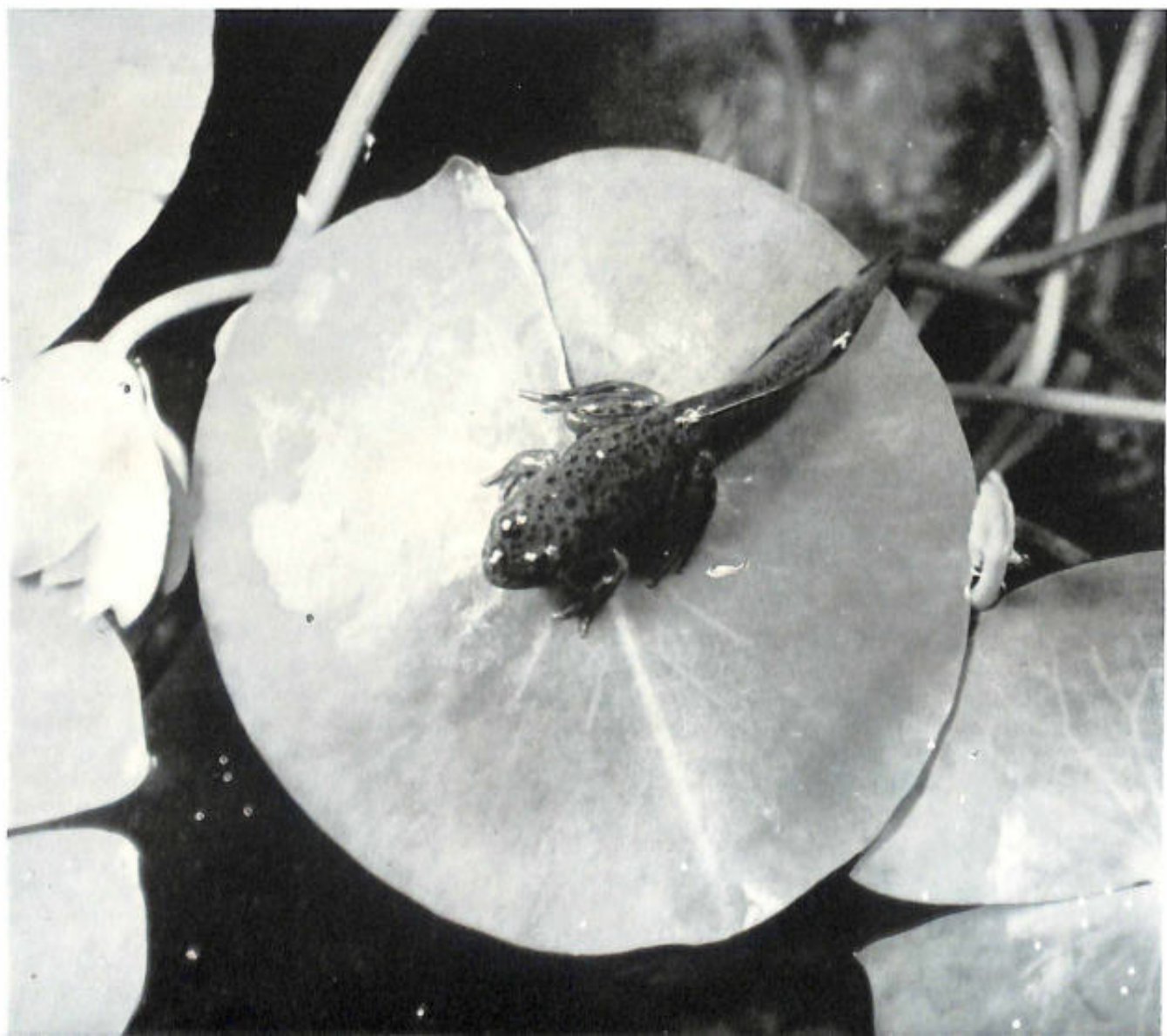






Larva of American bullfrog (*Rana catesbeiana*). Charles J. Stine, Jr.

Metamorphosing American bullfrog (*Rana catesbeiana*). Lynwood M. Chace







American bullfrog (*Rana catesbeiana*). A. van den Nieuwenhuizen

tion remains about the same, barring major catastrophes such as floods or excessively prolonged droughts. This is due partly to the very large number of eggs laid at breeding time—averaging some 5000 eggs from a single female in one season. If even a tenth part of the eggs survived, we should have a veritable “plague of frogs” worse than that recorded in the Bible.

It does indeed happen that sometimes in a relatively small area the conditions for the development of the larvae may be unusually favorable for a season, so that more than the average number of frogs are hopping around the pond’s edge or even invading the streets of a nearby town. This sudden abundance attracts every possible eater of young frogs. Swarms of crows dine on them as voraciously as they do upon locusts in a “locust year,” while tame house cats take to the sport of frog hunting. Unimaginable numbers of young frogs are crushed under the wheels of those modern juggernauts—automobiles. Furthermore, the biggest frogs devour some of the middle-sized ones,

who have first taken toll of the smallest ones, and so the balance is slowly restored and we do *not* have a world peopled chiefly by frogs.

Almost every country has its folklore about frogs. In medieval Europe frogs and toads were added to various witches’ brews to cure all manner of ailments. Their hibernation in mud during the winter was completely mystifying to the nonexperimenting man of a thousand years ago, and so people believed that there was some magic spell uttered to cause their disappearance during the cold months and to bring them back in the spring.

Stories of a “rain of frogs” are not as fabulous as they may seem to be. The United States Weather Bureau has verified the fact that frogs, and sometimes even small fish, may actually fall from the clouds when a tornado scoops up the contents of a pond and deposits it on dry land some distance away.

At the time when metamorphosed frogs are ready to leave the water, they frequently appear on the banks of streams in truly fabulous numbers. People



then say that it must have "rained" frogs, because so many of them are to be seen at one time. But as they are all of nearly the same kind and size, this is fairly good proof that they were all hatched at about the same time in the same pond and emerged within a few hours or days of each other to assume their land-dwelling existence. In these instances windstorms are not responsible for their abundance. Such a phenomenon takes place every year at about the same date, except when droughts occur to dry up the ponds, thus killing the tadpoles, or when some other catastrophe destroys them.

Another "story" even more prevalent but without the basis of truth is that there are vast fortunes to be made in frog farming. Every museum in the world probably gets dozens of letters a year from would-be frog farmers, who wish to know where they can buy breeding stock, how soon they can expect to flood the market with thousands of pounds of frogs' legs, and what is the current price per dozen for frogs' legs at the highest-priced restaurants. The sad and simple truth is that frog farming as such is not the highly profitable investment that hearsay would have us believe. The bullfrog, *Rana catesbeiana*, and two other relatively rare frogs are the only species native to the United States which attain sufficient size as adults to be acceptable to the market—and it is five years from egg to full adult in these frogs. With the high cost of labor in this country, no one could afford the artificial feeding of frogs taking so long to reach a marketable size. The best that can be done by the person who wishes to secure a small but steady supply of frogs' legs is to find a swampy area where bullfrogs occur naturally, and then try to keep out of it some of the frogs' natural enemies such as snapping turtles, wading birds, and voracious fish. Due to their own cannibalistic habits, the yield of marketable adult bullfrogs is strictly limited under even optimum conditions. But like fishing, perhaps the sport alone is reward enough for those who enjoy it. As for catching frogs for laboratory use, as the large biological supply houses do it, with their nets, seines, and other professional equipment, that is another story. Frogs for teaching purposes need not necessarily be the comparatively shy bullfrog, but may be the green frog or the leopard frog, both much commoner and easier to take in wholesale lots.

In this family, mating usually takes place in the water, to the accompaniment of much calling by the male. The North American leopard frog, *Rana pipiens* (Plate 63), has three distinct calls that seem to be correctly understood by others of its species. The regular sex call is used to direct the females and other

males to the breeding pond; the warning call is given when one male has been accidentally seized by another, and a sex-warning call is uttered by the male when he intends to clasp a female. A fourth kind of sound, more like a grunt, is given only by the female as a sign to an approaching male that she is not ready to lay her eggs.

When the female approaches the pond and first enters the water, the male swims around her, uttering his sex-warning call and thus apparently calming his prospective mate. He then clasps her pectorally, and lies full-length upon her back. Carrying her mate thus, the female next does a series of so-called "backward shuffles," alternating with rest periods. Finally the egg-laying posture is assumed, the female spreading her thighs and placing her heels together, the male raising his knees and planting his feet on her thighs. Eggs now appear in small clusters that are ejected with some force, almost as if automatically pumped out. They are further assisted on their way by the male, who arches and then straightens his back and presses his legs against the female's contracted abdominal wall, bringing their cloacas together at the precise time that the eggs are emitted into the area between their legs, where they are fertilized. The egg masses may float freely in the water or may be attached to the stems of water plants.

Most other species of *Rana* are essentially similar, but true nest-building accompanied by a complicated ritual is known in *Rana adenopleura* of China. Here each male makes a nest burrow in the bank of a pond by digging with his nose. All the males then call in chorus until the first female appears. The "song" then changes to a low, unmusical note continued by all males in the neighborhood until the female has chosen her mate. After that, the remaining males resume their first higher and more musical call. After amplexus, the eggs are left in the nest to hatch in safety from the depredations of egg-eating insects in the pond below.

*Staurois changanensis* from China does its courting by calling from the banks of a mountain stream in a note like that of a cricket. After the female appears, the male's clasp is axillary. She carries her mate until she finds a calm pool in the stream, whereupon she swims near or under a rock, lowering her head and pressing her vent against the stone. A triangular space between their hind legs is then formed by the pair, and the eggs are ejected and fertilized. They are attached to the stone by being pushed against it by the female's vent. She then throws off the still-clinging male by arching her body and shaking her legs, and although he complains bitterly, he soon lets her go.



Most frogs, excepting the bullfrog and a very few others, complete their growth in a single year, so that they are ready to breed the year following the egg stage.

Few wild creatures die a natural death from old age, and frogs are no exception to the rule. As soon as they become a little less alert through aging, and their leaping powers are reduced, they fall prey to one of the hungry animals that like frog meat. In captivity the true possible life span is probably often achieved, because "pet" frogs are protected from their many natural enemies and are usually fed a more complete and satisfactory diet than they could pick up in the wild state. A bullfrog, *Rana catesbeiana*, was reported to have lived seven years in a European zoo. Other frogs for which we know the approximate life span in captivity are:

North American leopard frog, *Rana pipiens*—nearly six years

South African speckled frog, *Rana adspersa*—five years

African tigrine frog, *Rana occipitalis*—five years

I once kept a green frog, *Rana melanota* (Plate 64), for several years. He lived in a moss-carpeted vivarium with a small pan of water sunk in the moss, so he could take a bath at will. He very soon learned to take strips of raw beef from my fingers, and waxed enthusiastic over earthworms, stuffing their wriggling bodies into his wide mouth with both hands to hasten the swallowing process. As he grew to adulthood, he never failed to call at the sound of a fire siren going by in the street, puffing his throat to half the size of an egg and "answering" as long as the siren could be heard.

Freaks occur among frogs, as they do among all animals. If the lack of conformity is too great a handicap, the frog having it is, of course, killed and eaten with considerable promptness. Thus a deformity, if hereditary, is prevented from being passed on to the next generation of frogs. The presence of an extra arm or leg, or even two of them, does not seem to be a serious handicap, however, as a five- or six-legged frog is reported with fair frequency.

Color aberrations are apt to be encountered more often, however. One hot August afternoon I was lazily weeding the crab grass out of the iris rim that surrounded my back-yard pool when off at the side among the stems of the Indian-club lilies, I caught a flash of color that certainly seemed out of place there—turquoise blue! I looked closer, and there squatting in the mud by the edge of the water was a bright blue frog. My other frogs were and always had been green

or greenish brown in color, but here was an off-beat, a stranger in their midst, and I had to examine him more closely.

After a chase I finally managed to clap my hand over him and brought him indoors to the vivarium for careful inspection. He was like my common green frogs in every respect excepting color, and there were some traces of the normal greenish tone on his arms and legs, although his back, sides, and head were brilliantly blue. It was apparent that he was a melano—the opposite of an albino—in whose skin only the darker pigment, blue in this case, had developed, while the lighter pigment, yellow, was almost wholly absent except in the patches of green on the limbs.

Under the microscope I had seen these dark and light pigment cells of normal frog skin, called melanophores and guanophores respectively. They appeared as odd star-shaped structures, which very slowly contracted or expanded under varying conditions of temperature, light, and humidity. The activity of these cells explains the ability of many amphibians and reptiles to change their color to a certain extent. The common toad, for instance, is usually tan or brown with a few darker spots, yet keep him in a dark place for a few hours and you will find a pale, pasty-hued creature when you release him. As he hops about in normal light, his color gradually darkens to its usual tones. Some tree frogs are also able to change color from a golden tan through gray to dark brown and sometimes green. Many reptiles, such as the true chameleon of Africa and the "false chameleon" of the New World, properly called the anole, can change rather rapidly through a somewhat similar range. They cannot change to resemble a Scotch plaid, nor will they burst in an attempt to do so if placed upon the plaid.

Fascinated by the lovely turquoise complexion of my new pet, I sketched and photographed him to my heart's content. I took him down to the office to show to an associate, who was also fascinated by the color. "Why don't you put him back in your pond and see if you can breed a race of blue frogs there?" he asked. My pond was small, relatively safe from marauding animals, and contained nothing but green frogs at the time, so in a few days I gave the blue frog his freedom on the very spot where I had first seen him. Several more times that summer I spied him on the banks of the pond, either taking his ease in the heat of the day beneath a sheltering leaf or watching for the next dragonfly to come close enough for capture. But the following summer my pond contained nothing but green frogs.

Then there was Buttercup. She was a bullfrog, but-





Sharp-nosed frog (*Rana oxyrhyncha*). Walter Rose

ter yellow in color on her arms, legs, and sides of body, but with an irregular oval patch of normal bullfrog color—grayish green—in the center of her back, and another spot on her head. I first met her when she was brought to my office by one of the government's Bureau of Fisheries men, who had found her in a fish hatchery in New Jersey. Being a bullfrog, she was much more aquatic than my "blue" green frog, and so was content to sit in the shallow water of my aquarium hour after hour, seldom climbing out upon the landing stage of sand and smooth stones provided for her. I was kept busy catching moths and grasshoppers for her at first, but she soon learned to eat little bits of chopped beef which I presented to her on a wiggling straw. If her food did not move, she failed to see and recognize it as something to eat, but if I pulled the straw to which the meat was attached away from her, she hopped after it and soon seized it in her mouth.

Fortunately I made a photograph of her soon after she arrived. In a few weeks I noticed that the area of normal-colored skin had enlarged, and that patches of true bullfrog color were appearing on her arms and legs, which before had been immaculate golden yellow. This was interesting, for it showed that she was not a true albino and that in time the whole area now yellow might change to the customary greenish brown. I made other photographs every few weeks, showing that the normal color continued to increase in area.

Almost a year after I first got her, I regret to say that poor Buttercup forced off the wire cover of her cage one week end, and the following Monday morn-

ing I found only a pathetic little dried-up frog in a corner of my office floor. She had failed to find any moisture after her escape from the aquarium, and doubtless in a few hours her body tissues had completely dehydrated, resulting in her death, so we never knew if she would have assumed a completely normal bullfrog color in time.

No one who has ever read Mark Twain's celebrated tale, "The Jumping Frog of Calaveras County," will be surprised to learn of the extraordinary leaping ability of the bullfrog. Every year the townspeople of Calaveras stage a frog-jumping contest, which brings them much revenue from tourists even if it does not settle once and for all whose frog is the best jumper. For the frog contestants themselves do not have much interest in setting any record. Most of them sit with a dazed stare when they are tumbled out of their boxes into the center of the ring, and eventually all of them scatter in every direction except the desired one so that it is hard to determine whether any real jumping record is made by one of their number.

Tests of the jumping ability of various frogs have, however, been carefully undertaken in the quiet of the laboratory. We learn from these that the bullfrog, *Rana catesbeiana*, largest of the North American frogs and having a maximum length of some 8 inches, can jump nearly nine times its own length. The leopard frog, *Rana pipiens*, measuring 5 inches in length, outdoes it by leaping almost thirteen times its length, being the best jumper of any of the North American Ranidae tested. But these are far exceeded by small members of the family Hylidae, especially by the cricket frog, *Acris gryllus*, which can jump a distance of more than thirty-six times its length.

This record is again shattered by the African *Rana oxyrhyncha*, one of which averaged nearly forty-five times its own length on each of three successive leaps in the famed Frogolympics contest held at Capetown in 1954.

Frogs are, however, put to more practical uses by man than entering them in jumping contests. In ancient Rome the famous banquets of Lucullus, the gourmet, were undoubtedly graced by dishes of frogs' legs prepared in the most exotic style. The frog which provided the legs was the European edible frog, *Rana esculenta*, and it must have been a favored item of food far back into prehistoric times, since it was plentiful in almost every pond and was besides one of the few creatures eaten by the cave man that did not try to fight back. It required considerable agility on the part of the hunter to catch one in his bare hands, then as now; hence frogs' legs were probably never a main article of diet but only a rare luxury. In southern



Asia, the Indian bullfrog, *Rana tigrina*, undoubtedly serves as food for animals and men alike wherever it occurs.

The European edible frog is mostly aquatic, although it may sometimes migrate overland from one pond to another close by, and may also come out to hunt on shore by night. It can feed either underwater or on land. It devours large worms underwater, using its hands to stuff the wriggling prey into its mouth. On land its food consists of insects, chiefly beetles. It has also been known to capture and devour butterflies, on which it leaps without hesitation if the insects flutter near its pond.

Breeding time is announced by the loud, rattling croak of the male. This sound is amplified in the two vocal sacs, one on each side of the throat, which may be inflated to the size of hazelnuts. The call, which may be repeated again and again, lasts two or three seconds, after which the sacs deflate quickly. When numbers of males occupy the same pond the noise goes on almost continuously night and day for five to ten days, to the discomfort of human inhabitants of

nearby dwellings, for whom sleep is thus rudely interrupted. Mating usually takes place in May or June, depending on the temperature. The croaking is kept up intermittently all summer, but in subdued volume. It has been likened to the quacking of ducks. An imitation of the call by a human observer who cannot be seen by the frogs will set them to "singing," as will the passing of a train or the hum of an airplane overhead. The female's call is less frequently heard and differs from that of the male, sounding something like the squeaking of a chaffinch.

Breeding pairs usually go to the shallow margin of their pond, where the water is from three to six inches deep and where plenty of water plants are growing. While mating pairs tend to congregate in a definite spawning site at first, those which mate later may move to another part of the pond to spawn. Although extremely timid and wary at other times, frogs seem to lose their fear of human beings at breeding time, so that accurate observations may be made on their activities.

At the beginning, the sexually mature males gather

Edible frog (*Rana esculenta*). A. van den Nieuwenhuizen





at the spawning area and commence their calling. Their voices guide some of the females to the spot, but other females—probably those in whose bodies the eggs are not quite ready for laying—remain at a distance. Thus there are often several males to a single female. There is little rivalry among unmated males, and a mated pair can remain near a crowd of males without being molested. Unmated males search continually for a mate. With their small intelligence, they do not recognize a female by sight when they see one. If a male should jump on the back of another male and attempt to clasp him in a sexual embrace, however, the seized one croaks or moves away, at which signals he is instantly released, since both these reactions announce to the searching male that the seized one is of the wrong sex.

A mated pair seeks out a bed of water weed on which to lay eggs. These are produced in many small emissions occurring at intervals for the next day or two, after which the sexes separate. The total number of eggs laid by a female edible frog in one season may number between 5000 and 10,000, although the small, separately laid clumps seldom average over 300 eggs and may contain even fewer.

The larva hatches in a week to ten days, but its subsequent growth is often irregular, depending partly on temperature. In warm weather metamorphosis takes place after three and a half months, when the larva has grown to a length of about an inch. By autumn of the second year some have reached a length of over 2 inches. Sexual maturity probably occurs in two years. The maximum length of an old female, which exceeds the male slightly in size, is 3 inches. In winter the adults hibernate in mud at the bottom of ponds or in holes along the water's edge. The young

ones usually hibernate on land under stones or fallen logs.

The edible frog occurs over the whole of Europe, excepting Spain, as far as the Caspian Sea. Other closely related—and equally edible—forms take its place in Spain, North Africa, and southern Asia.

The flesh of all frogs and toads is edible, although most kinds are of such small size that it is not commercially feasible to catch them for modern markets. But in meat-hungry countries even the 2-inch-long rice-paddy frog, *Rana limnocharis*, is not scorned as a food item. Some American soldiers marching into a town in Korea found strings of these little frogs gutted and hung up to dry from the rafters of the houses.

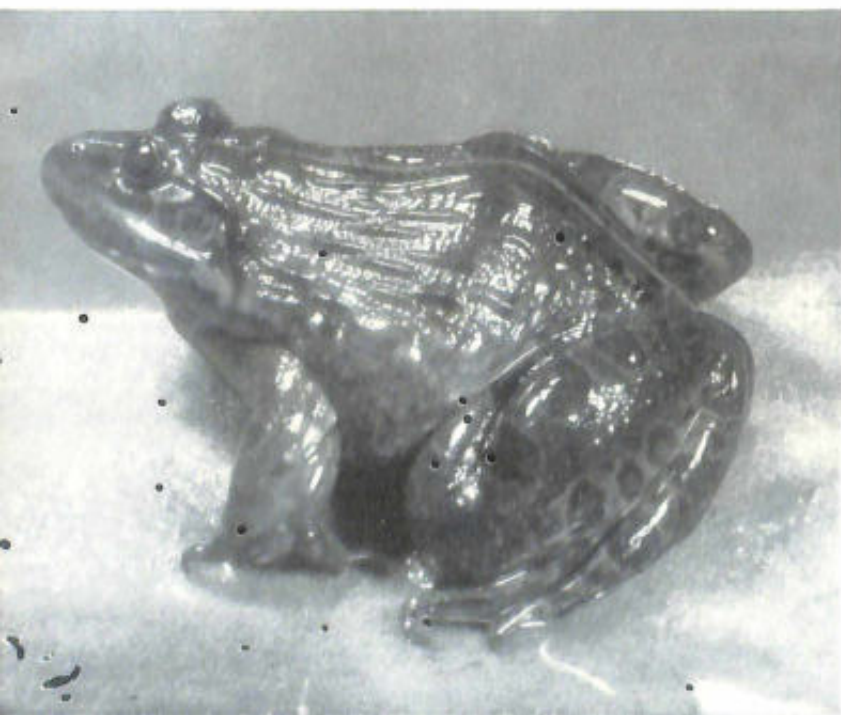
Unusual frog calls frequently give their popular names to the frogs that utter them. Such is the case with the carpenter frog, *Rana virgatipes*, whose individual note sounds like two carpenters striking ~~not~~ not completely in unison, while a chorus of many frogs is like a whole crew of hammering workmen. Because of its liking for sphagnum bogs along the coastal plain from New Jersey to Georgia, it is also sometimes called the sphagnum frog. It is a little over 2½ inches long and is not at all easy to find, since its color is so similar to that of the dark waters of the bog.

The pig frog, *Rana grylio*, is one of the largest of the North American species, reaching a length of nearly 6½ inches, and it might rank with the bullfrog as a table delicacy if it were not so difficult to catch. It prefers an aquatic life among floating vegetation in lakes and swamps, from South Carolina to Florida and eastern Texas. Its common name comes from its call, and a chorus of these frogs has been likened to a herd of swine in full voice.

The poisonous character toward other frogs of the skin of the pickerel frog, *Rana palustris* (Plate 66), has been mentioned on pages 107 and 194. It has nevertheless one of the handsomest of patterns—a double row of nearly square brown spots on a metallic copper or golden ground. When the frog leaps, a totally different effect is given by the display of the brilliant yellow of the usually concealed inner surfaces of the hind legs. Its maximum size is about 3½ inches. Its voice is relatively weak and not musical, sounding more like a snore than anything else. It is found over nearly the whole of eastern North America from southern Canada to South Carolina, west to Wisconsin and south to eastern Texas.

The red-legged frog, *Rana aurora*, occurs from British Columbia to southern California, living in permanent ponds and marshes, often traveling considerable distances from water into damp woods in its

• **Indian bullfrog** (*Rana tigrina*). Gerhard Budich







Edible frog (*Rana esculenta*). Arthur Christiansen: Annan Photo Features.

search for food. Its call, a guttural growl, may be heard during the breeding season from February to May. Its size may be up to 5 inches. In captivity it has been known to live for thirteen years.

A variety of colors decorates the skin of the wood frog, *Rana sylvatica* (Plate 65), for it may be pale tan or grayish through orange and sunset pink to dark gray-green, although it never changes the brown "robber's mask" encircling the snout as a narrow line and widening behind the eardrum into a large triangular patch. It ranges farther north than any other North American frog, being found in southern Alaska as well as over much of Canada, and extending into the United States southward to Georgia and South Carolina. Its brown mask suggests its relationship to

the European *Rana temporaria*, which has a similar appearance and equal tolerance for cold climates.

The mink frog, *Rana septentrionalis*, prefers the cold climate of Minnesota and northern New York State through Manitoba, Labrador, and the Maritime Provinces of Canada. Its skin produces an odor like the scent of a mink, or more like the smell of rotten onions according to some observers. Nonetheless it is a graceful and delicately modeled 3-inch frog. It prefers to live among clusters of water lilies, where it can hop from pad to pad.

*Rana hosii* from the East Indies (Plate 70) has large toe and finger disks resembling those of most of the Rhacophoridae and Hylidae. The structure of its vertebrae, as well as other skeletal differences, prove



that it is a true Ranid, in which the digital disks for climbing give it the added safety of an arboreal life.

*Rana subsigillata* (Plate 69) from western Africa has the streamlined body and webbed feet that go with an aquatic existence, but its exact habits and development have not yet been recorded. The life histories of other frogs, among them the Moeru frog, *Rana moeruensis*, the African spotted frog, *Rana subpunctata*, the warty frog, *Rana tuberculosa*, and Blyth's frog, *Rana blythi*, are still in the process of being studied.

We are always interested in the giants among any group of animals. The largest known frog is *Rana goliath* (called *Gigantorana goliath* by some specialists), which comes from the Belgian Congo. The first specimen captured measured nearly 10 inches, and an

even larger one got away, just as the biggest fishes have a habit of doing. It lives in the deeper pools of the river and is said to be excessively shy. The natives catch them occasionally with scoop nets. Live ones very seldom are sent out of Africa, even at the high prices offered by dealers and zoological gardens everywhere, as their thigh bones are supposed by the natives to be endowed with magical powers for bringing good luck.

I am often asked if it would be possible to cross the goliath frog with the North American bullfrog and thus breed a large and accessible hybrid to supply our tables. This experiment has never been tried because of the extreme difficulty of getting goliath frogs out of their native haunts. While various species of frogs have been known to cross, both naturally in the wild

Carpenter frog (*Rana virgatipes*). Jack Dewar





state and artificially under controlled laboratory conditions, it seems very unlikely that a successful cross could ever be made between the goliath frog and any frog from the northern hemisphere. While the breeding habits of the former are not yet on record, the height of its breeding activity probably comes in springtime, which in countries below the equator corresponds to the autumn of the northern hemisphere. There would probably always be a natural barrier between matings of the goliath frog and any of the larger frogs from the northern hemisphere. Artificial insemination could be tried by keeping sperm from one species until the eggs of the other were ready to be laid, but it is by no means certain that the resulting larvae would develop naturally, as a young bullfrog requires five years to mature while the time required by the goliath frog is as yet unknown. The cost of the labor involved would not permit experimenting on any large scale with so little prospect of commercial profit as an end result.

Although the Ranidae from the northern hemisphere, and even some from Africa, look a good deal alike and could be recognized by everyone as frogs, there are certain members of this family that display some very peculiar physical characteristics.

We have noted elsewhere that many kinds of salamanders breathe with other structures besides their lungs—with their outer skin, with sinus-containing toe tips, with the roof of the mouth. In the frog world we have one that augments its regular lung intake of air by breathing through its "hair."

Speaking of hair on a frog may seem ridiculous, but it is the simple truth when the frog is *Astylosternus robustus*, the hairy frog of the Cameroons. The adult males display an odd growth of fine glandular filaments resembling hair on their sides and along the thighs. These short vascular papillae correspond to the finer branches of gills; they are presumed to compensate for the much reduced lungs of this frog. Their occurrence on the males only at breeding time may be due to an increased metabolism during this season and to the need of the heavily muscled male for additional oxygen. The female also has a thickly vascularized integument, but she lacks the "hairs" of the male.

A parallel to these hairy gills is found in the fish *Lepidosiren*, where similar hairs develop on the brooding male fish, probably assisting him to secure enough oxygen without leaving the egg burrow.

Another peculiarity of the hairy frog is that three of its toes have their ends bent sharply at right angles to the next joint, with the bony tips projecting outside the skin, thus forming a set of "claws," the function of which has not yet been ascertained.



Woodfrog (*Rana sylvatica*). Karl H. Maslowski

Common European frog (*Rana temporaria*). Erich Sochurek





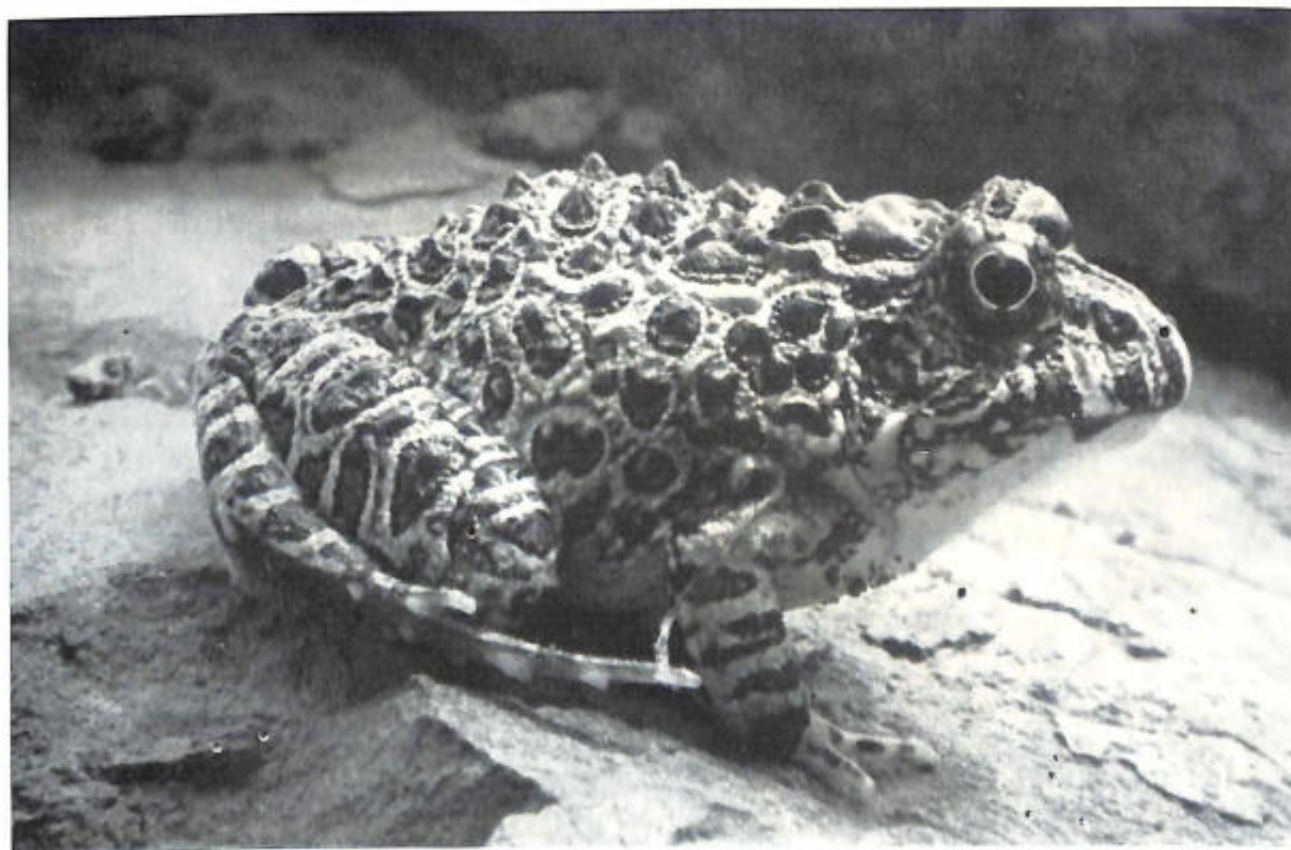






Moeru frog (*Rana moeruensis*). G. F. de Witte: Institut des Parcs Nationaux du Congo Belge

Warty frog (*Rana tuberculosa*). G. F. de Witte: Institut des Parcs Nationaux du Congo Belge



Common European frog (*Rana temporaria*).  
Walter Rohdich: Annan Photo Features





African spotted frog (*Rana subpunctata*). G. F. de Witte: Institut des Parcs Nationaux du Congo Belge

Several other species of *Astylosternus* are known, but while they have the bent toes and projecting bony tips, none of them has any "hair." At least two of the true frogs of Africa, *Rana mascareniensis* and *Rana christyi*, have similarly bent phalanges without the projecting claw.

Some small African ranids have no vomerine teeth, the possession of which marks most of the other members of the family. Two of these genera are *Arthroleptis* and *Phrynobatrachus*, both having many species and looking much like the true frogs of the genus *Rana* except for their smaller size. They are forest dwellers, hopping about the forest floor or inhabiting the brushy areas of more open country. The life histories of many of the species belonging to these genera have not yet been studied, but at least two species of *Phrynobatrachus* are known to lay their eggs in pools, while one species of *Arthroleptis* deposits them in shallow burrows on land.

Members of the genera *Cardioglossa*, of the rain forest of the Belgian Congo, and *Schoutedenella*, of the Katanga region, have the third finger greatly elongated in the males. In this respect they differ from all other frogs. Another odd African genus is *Phrynosoma*, from Mozambique and the Cameroons. It has a large head and elongate, spiky teeth that have a single point, instead of being bifid as are the teeth of frogs of the genus *Rana*.

It seems from the profusion of diversified ranid frogs found in Africa that this continent is the center of differentiation. A single genus, *Rana*, reaches the New World, extending through North America and through Central and northern South America, as we have noted.

We know that it is usually unsafe to make general statements, and when we say that all members of the genus *Rana* lay their eggs in water we must qualify

that statement, because sometimes *Rana grayi*, Gray's frog of South Africa, does not. Eggs of this frog have frequently been found in little cup-shaped depressions in the soil, definitely above the highest possible water level of the nearest pool. Fertile eggs have likewise been found in a damp cellar. The young develop in the hard little egg capsule, absorbing moisture from the nightly dews and occasional rains. Several weeks of completely dry weather may be safely passed by the tadpole inside its capsule, while tadpoles in shallow ponds might die if the ponds dry up before metamorphosis can occur. But at the advent of the rainy winter, the larvae wriggle out of the eggs and into the nearest rapidly filling pool, where they change rather quickly into young frogs. Gray's frog also places its eggs in rather deep water sometimes. There they have time to develop and grow before the dry season. The tadpoles of the land-hatching and of the water-hatching forms have no mouths for several days after leaving the egg. Later a mouth appears and metamorphosis goes on in the usual way. The adults live in tall grass and can swim if they enter water, but as their feet have scarcely any web to support them in water, they soon drown if compelled to swim for long.

The dusky-throated frog, *Rana fuscigula*, also from South Africa, has the feet nearly fully webbed and is essentially aquatic, seldom being found far from water. It is a little more than 3 inches long, and when it leaps into the water on being disturbed it makes a very perceptible splash. The voice is a loud, monotonous croaking, kept up during mating activities. Eggs are sometimes attached to weeds or stones in running water, and they number a thousand or more from a single female. The tadpoles hatched under such conditions often become very large, some from deep, cold parts of the stream measuring 4 inches and occasionally up to 7 inches. Their full metamorphosis is delayed in deep water, as they are known to remain in the tadpole stage for two or more years. But if some tadpoles make their way into shallow hillside trickles, they complete their metamorphosis much earlier, at 1½ inches in length. The accelerating factors seem to be the higher temperature of the water, as well as the stimulus to limb growth of the constant contact of the tadpole's lower surface with the ground.

The tiny chirping frog, *Arthroleptella lightfooti*, from South Africa, has a curious cricket-like chirping call, usually coming from a clump of moss growing near a spring or water seepage. These frogs vary considerably in color from brick red to brown or black. The relatively large eggs are stuck in clusters on damp moss, where the froglets hatch as soon as the



hind legs have appeared and wriggle about over the moss until the front legs also develop. In a few more days the tail is absorbed, and in a week or ten days after hatching, the froglets,  $\frac{1}{3}$  inch long, hop about to catch such minute insects as they can find. These frogs inhabit only mountainous regions, where the rushing streams swollen by heavy rains would make living impossible for such a small, weak tadpole if it were hatched in water in the usual way.

Smith's frog, *Phrynobatrachus natalensis*, lives in Transvaal and Natal. It lays up to four hundred very tiny eggs which float in a lacelike film on the surface of the water. The mother often does not show much judgment in her choice of puddles in which to lay, as many of them dry up, causing a very high infant mortality. One of the smallest frogs in the world is its close relative, the Chitjala frog, *Phrynobatrachus chitjalaensis*, which measures only  $\frac{1}{2}$  inch when fully grown. This species is found in Nyasaland. The micro frog, *Phrynobatrachus capensis*, is  $\frac{3}{4}$  inch long and comes from the Cape region in Africa.

While most frogs are timid and depend on instant

flight for their very lives, the dagger frog, *Babina holsti*, has an effective weapon which it does not fail to use upon provocation. The thumb, lacking in most of the tailless amphibians, is well developed in this frog, being a long, pointed bone, really a spine, since it is sharp at the end and is covered only by the skin. When picked up, the dagger frog grasps a man's hand in its strong arms and presses the spurs of the thumbs into his flesh, even drawing blood. This frog is confined to the highlands of Okinawa in the Ryu Kyu Islands, where its native name is "wakubichi." It is extremely active and difficult to capture, as it lives in hollow trees and in crevices among rocks. Its flesh is valued as food, and it was formerly used as medicine by native doctors.

Another genus of frogs with enlarged thumbs is *Petropedetes*, of which some half a dozen species are known from West Africa. The swimmer, *Petropedetes natator*, is found among rocks in the mountain torrents of Sierra Leone. It swims powerfully, as its name indicates, and is equally expert at jumping. It is said to cling to rocks and to the roots of trees over-

Blyth's frog (*Rana blythi*). Robert F. Inger





hanging the water by means of its strong digital disks. *Petropedetes newtoni* of the Cameroons and Gaboon has a long spine on the thumb, and although nothing has been recorded of its habits, the male probably uses this spine for defense as well as to hold the female in breeding.

Members of the genus *Platymantis* from New Guinea and Borneo are not swimmers by nature, preferring to make their homes on land. Even the eggs

hopping on dry land, where they seldom come. The tadpole of *Ooeidozyga laevis*, found in many of the East Indian islands, is remarkable for its small mouth, surrounded by a toothless, horseshoe-shaped lip, and having a central horny beak for scraping its protozoan food off the leaves of water plants.

Some frogs are so puzzling to us in their structure, not to mention their life histories, that they have been shifted around from one family to another, without



Christy's frog (*Rana christyi*). Robert F. Inger: Institut des Parcs Nationaux du Congo Belge

are deposited on the ground in damp soil, and the tadpoles develop in the egg, without undergoing the free-swimming stage before metamorphosing. *Platymantis Boulengeri* (Plate 67) was only recently discovered in Borneo.

The aquatic frogs very common in rice paddies, slow streams, and pools in southern Asia, the Malay Archipelago, and the Philippines belong to the genus *Ooeidozyga*. None is over 2 inches in length. Their short, heavily muscled legs and completely webbed feet are ideal for swimming, but are not so good for

any full agreement among zoologists as to just where they truly belong. Among these are the African genera *Cacosternum*, *Hemissus*, and *Anhydrophryne*, which had formerly been grouped with the Microhylidae because of certain skeletal characteristics, but which now are believed to have evolved from a ranid ancestor and therefore should be grouped with the Ranidae.

*Cacosternum capense*, the cross-marked frog, was discovered on a golf course within five miles of Capetown, South Africa, where no frog was thought to live because this area is totally dry for nine months of the



year. Nevertheless the rains bring it out in considerable numbers from its subterranean burrows, and of course the rains also keep the golfers at home. Thus it was almost by accident that its presence was finally discovered, since it is excessively secretive, burrowing deeply and never coming out by day except during the rain. Strange to say, the males apparently outnumber the females by six to one. It is not often that such disparity in the numbers of each sex is to be noted. The adults measure  $1\frac{1}{2}$  inches in length. Just before mating, the males produce sounds far in excess of what might be expected from their small size, but fortunately for the human beings within ear range, the calling lasts only until pairing has taken place. About four hundred eggs are produced in a single laying. After breeding, the frogs lie for days buried in the sand of shallow puddles, with only the tip of the nose and the projecting eyes showing. During dry weather they are forced to remain underground to keep from being desiccated. Their skin is quite warty above, with small green or orange spots, and a dark X mark between the shoulders gives them their common name. The secretion from their skin causes the quick death of other frogs brought into the same vivarium. Their method of locomotion is to make a series of short hops, the legs being held out at the sides, instead of tucked underneath in the manner of most of the better jumpers of other families. Like a mouse, they can run quickly for short distances. When at rest they appear very fat and flat as compared to other frogs, because they actually lie on their stomachs instead of sitting on their bent legs and arms.

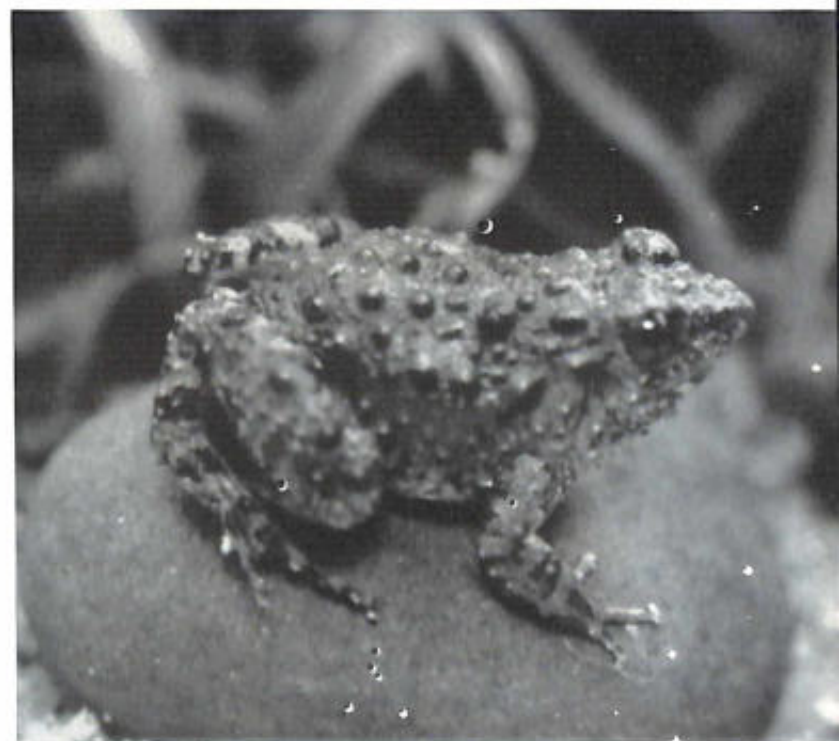
Rattray's frog, *Anhydrophtyne rattrayi*, protects its eggs by laying them in a small hole in the ground, where complete metamorphosis of the tadpole takes place before hatching. About twenty large eggs constitutes the clutch for the species. While the tadpoles in the egg stage need some moisture, they drown if taken out of their hole and placed in water.

One of the burrowing frogs which can swim is *Hemissus marmoratus*. This frog is noteworthy for its method of making tunnels. Instead of having spade-like projections on the hind feet, which most burrowing frogs of other families possess, this one dives headfirst into the soft soil and uses its piglike snout for digging. The sharp nose is further accented by a very receding under jaw. The eggs are laid under the bank of a pool in some small cavity above the water level. The female stays with them until they hatch; then she tunnels through the earth from her nest to the water, and the tadpoles slide downward in a mass. When full grown the animal measures  $1\frac{1}{2}$  inches in length.



Dusky-throated frog (*Rana fuscigula*). C. F. de Witte:  
Institut des Parcs Nationaux du Congo Belge

Natal frog (*Phrynobatrachus natalensis*). Walter Rose







Two views of Pig-nosed frog (*Hemisus marmoratus*). The variation of skin roughness within a species is often great, especially at breeding time. Photographs by Robert F. Inger and G. F. de Witte, both courtesy Institut des Parcs Nationaux du Congo Belge.





*Mantella aurantiaca* (Plate 68) with its short legs and small, broad body does not outwardly reveal its relationship with the Ranidae. Anatomical comparisons have proved without doubt that it belongs to that family, instead of to the Dendrobatidae, with which it was grouped at its first discovery.

## The Rhacophorids

(Family Rhacophoridae)

In Africa, Madagascar, and southeastern Asia occurs a host of brilliantly colored frogs of the family Rhacophoridae. In foot structure and other external features they are much like those of the family Hyliidae, but there are enough significant skeletal differences between them to warrant their being placed in separate families.

The African genus *Hyperolius*, comprising over two hundred species often called sedge frogs, displays perhaps the most fluctuating patterns and the most brilliant color combinations to be found in any related group of frogs. One of these, *Hyperolius argentovittis* (Plate 71) from Tanganyika, has the delicate structure and attractive coloring that makes it a desirable inmate of the zoo or the home vivarium. Other color combinations include black with flaming orange spots or deep emerald green with scarlet collar, while still others are pearl white with an array of golden dots on the back and legs—all these colors being subject to changes due to temperature, humidity, and the state of excitement of the frog.

Nearly every lake has several different species of rhacophorid frogs living among the water plants near the shore, for such places are fine hunting grounds for mosquitoes, gnats, and other small insects.

During the dry season when the shallow ponds and streams disappear, the frogs retreat into crevices of rock or into burrows in the ground, where some moisture remains even during the long months of drought, and there many of them manage to survive until the coming of the abundant rains provides release for the adults as well as a multitude of spawning places for next season's crop of wriggling tadpoles.

A bee in the heart of a rose is quite familiar to us, but a frog in a lily cup is a trifle more unusual in some parts of the world. In South Africa, however, the arum frog, *Hyperolius horstockii*, takes its popular name from its habit of nestling deep in the center of the arum lily—in fact two or three may share the same flowery hiding place, where their ivory skins make them nearly invisible against the white spathe,

while the insects attracted by the flower's perfume fall ready prey to the frogs' insatiable appetites. If something larger than an insect disturbs their rest, however, they promptly move off. The first flying leap takes them to other lily stalks nearby, where some perhaps pivot, hanging by a single toe and swinging around the stem to disappear from view on the far side. Only when greatly frightened do they dive into the shallow water below them, where they become invisible among the lily roots. The disks on their toes give them a considerable leaping ability of about twenty-four inches over a level surface and eighteen inches upward, their own length being only an inch. The call of the male is a loud "chee, chee, chee," and



Arum frog (*Hyperolius horstockii*). Erich Sochurek

the large vocal sac when inflated makes him appear twice his normal size.

The arum lily is in bloom for only a part of the year, so when the flowers have faded the arum frogs must make do with other plant hosts. They are then no longer ivory white, but assume a dark brown tone with a silvery or greenish stripe along each side, resembling the brown stems on which they rest. Their attraction toward white objects during the flowering season of the arum appears to explain their habit of piling one on top of another, as many as three deep, in the vivarium, where the whitest object at hand is one of their own kind.

The female arum frog lays her eggs in November (late springtime in South Africa) in clusters of ten to thirty attached to the roots of water plants. Instead of scraping algae in the usual manner, the tadpoles





De Witte's leaping frog (*Afrixalus wittei*). G. F. de Witte:  
Institut des Parcs Nationaux du Congo Belge

seem to suck in the minute organisms found in every stagnant pool.

Larger frogs such as *Rana edulis* are known to devour sedge frogs. Countless numbers fall prey to wading birds, snakes, and other enemies that lie ever in wait for such choice morsels. Their own food consists almost entirely of flying insects.

Color variation is likewise the rule in the marbled rush frog, *Hyperolius marmoratus*, which sometimes has a black-and-white-striped pattern set off by delicate pink tones on its sides and limbs; in other regions, however, the same species may appear in a completely different dress, so that the laboratory scientist, who may never have had an opportunity to see the live frogs in their own native haunts, may be hopelessly confused in his efforts to identify them. The "favorite" colors of this widely distributed African form are black and green, black and yellow, brown and green, and brown and yellow, in addition to the black and white striping just mentioned. The skin is very sensitive to light intensity, as it is in the arum frog; hence bright light often causes the colors to fade temporarily, until the variegation or striped pattern can scarcely be made out.

The five-lined sedge frog, *H. quinquevittatus* (Plate 72), is found from Angola to Tanganyika Territory. When fully grown, it measures just over an inch. In most males, the lines are quite apparent, but in females this pattern is generally less distinct, rendering them much less easy to distinguish from the many other species living in the same area.

Another group of striped frogs are those of the genus *Kassina*, an African group closely related to *Hyperolius* but somewhat less graceful in contour. They are nocturnal and therefore seem to have little need for stripes, which help a diurnal frog to find camouflage among the grass stems.

*Kassina senegalensis* has a voice which resembles the popping sound made by withdrawing a cork from a bottle. To produce this remarkable sound effect, it seems to inflate not only the vocal sac on the center of the throat but also some accessory lateral branches. The adult grows to a length of just over 1½ inches. It has beautiful dark brown stripes on a lustrous olive-green background. The tadpoles are always hungry, and gnaw the leaves and stems of plants growing in their pool.

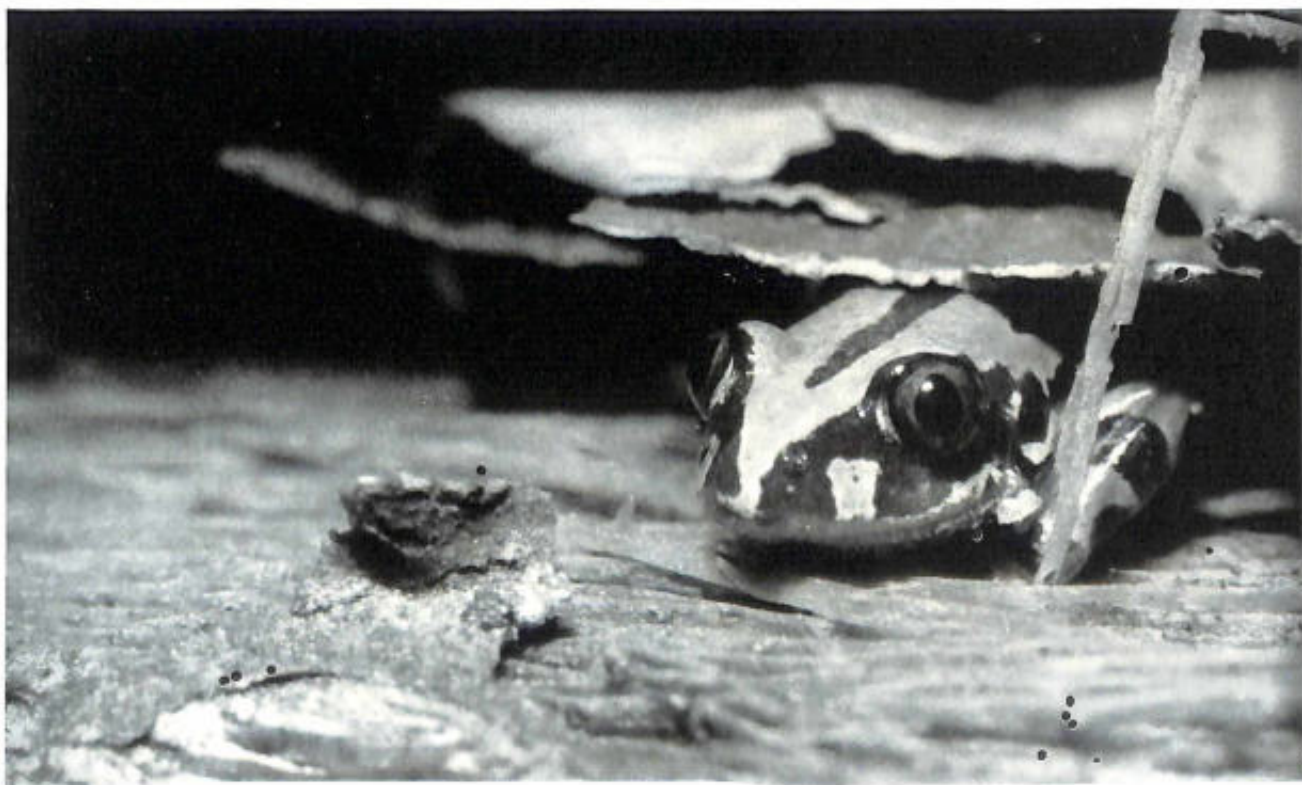
The African gray tree frog, *Chiromantis xerampolina*, from central and southern Africa, habitually remains by day in some chosen spot, leaving it only at night to forage and returning to the same place at the crack of dawn. This takes place all during the long dry season, but at the very first rain it moves out of





Lebeau's frog (*Leptopelis lebeaui*). G. F. de Witte: Institut des Parcs Nationaux du Congo Belge

Senegal frog (*Kassina senegalensis*). Robert F. Inger: Institut des Parcs Nationaux du Congo Belge







Reinwardt's gliding frog (*Rhacophorus reinwardtii*).  
Hans Rosenberg

the wet and into a completely dry spot, such as a house. This is the reverse of the behavior of most frogs, which are prompted to seek moisture whenever it is available. Nevertheless the African gray tree frog manages to maintain a moist skin even in the hottest and driest weather. At breeding time a foam nest consisting of a thick, mucus-like liquid is produced by the female, who beats it to a froth, using her hind legs as whips. The male joins her in the froth-whipping, which usually takes considerable time to complete.

The egg mass is always placed in a tree or large bush just above a water hole. In a few hours the hot sun has baked the outer layer of froth into a hardened crust. About 150 eggs are laid in each mass previous to the hardening of the outer layer. In three or four days the eggs hatch and the tadpoles sink to the bottom. The lower crust then breaks and the larvae fall into the water below. During this time the mother has stayed on her nest, clasping it with her arms and legs. If she is removed during the period when she normally "sits" on her eggs, the ball of froth hardens too much on the outside, so that the young cannot escape, and they soon die. This frog grows to a length of 3 inches. The toes are webbed, with their tips expanded into disks. The fingers are opposable, so that the frog can really clutch a twig. Most frogs do not have opposable fingers, and when they cling to an upright it is by the suction of their digital disks alone, with their fingers and toes more or less parallel and in the same plane. The gray tree frog is soberly colored, its skin being dark gray to nearly white and lightly marked with darker lines and spots.

Males of *Hylambates natalensis*, 2-inch-long frogs from South Africa, are pugnacious at breeding time, pushing each other and shrieking in a voice much higher in pitch than their normal tones. Even with this disturbance, the females do manage to get their three hundred large yellow eggs laid in a mass in holes or under leaves near water. The tadpoles are elongate and rather eel-like in shape, and they are said to move like eels as they crawl in a long chain toward the water after hatching. These tadpoles are capable of very rapid swimming, but usually move slowly unless disturbed. They can jump three inches out of the water by a movement of the powerful tail. They are said to survive in stagnant water as well as in fresh, clean water.

*Hylambates brevirostris* of equatorial Africa has a habit of brooding that somewhat resembles that of *Rhinoderma darwinii*, the South American representative of the family Rhinodermatidae. The female *Hylambates* takes the new-laid eggs into her mouth, where they are retained until they hatch as fully developed frogs. She does not feed during the entire period of their incubation, but her little family enjoy the most complete protection during this very critical period of their lives.

*Hylambates maculatus* (Plate 75) from the southeastern part of Africa, including Zanzibar, is one of the best known of the genus. It is hardy in captivity.

The lesser banana frog of Africa, *Megalixalus stuhlmanni*, sometimes has translucent flesh on its lower surfaces, allowing the limb bones to be seen



clearly through it. The adult, which measures  $1\frac{1}{4}$  inches in length, is golden brown with darker stripes.

Some of the Asiatic rhacophorids live high above the jungle floor in the topmost branches of trees, leaping from branch to branch in their vigilant search for small flying insects, a vast number of which must be consumed in the daily diet of a single frog. Their eyes usually have vertical pupils that expand in the weak light, thus enabling their owners to see the most minute insects even in the constant shadow of heavy forest. The toes and fingers of some species are fully webbed; these webs were once thought to resemble wing membranes, from which came the popular name "flying frog" given to the Malayan *Rhacophorus reinwardtii*. Of course these frogs do not actually fly, since the act of flying demands differently developed bones and muscles than those possessed by any frog. But

they do glide from a high tree trunk diagonally down and out for a considerable distance, perhaps forty or fifty feet, to the base of a distant tree. The toes and fingers are rigidly spread during their glide, and the underside of the body is held concave so as to get the greatest buoyancy from the air, which does in this instance sustain the animal's slight weight. Thus the direction and length of glide can be controlled to some extent.

In parts of Malaya the brightly colored *Rhacophorus dennysi* is venerated by a religious cult, and on holy days one of these frogs is carried in a procession in its own sacred chair.

The Japanese *Rhacophorus schlegelii*, like some of the African frogs, uses a froth-beating technique prior to egg laying. The female's hind legs beat up the froth, while the male holds her tightly around the loins in the

Japanese gliding frog (*Rhacophorus schlegelii*). Carl Gans





sexual embrace, helping to draw out her strings of eggs with his hind feet, at the same instant fertilizing them with a liberal drenching of sperm cells. The foam nest is usually placed in a moist hole in the ground, where the young transform completely without having to enter any standing water during their larval existence.

One of the rhacophorids having the widest distribution is *Rhacophorus leucomystax*, occurring from the eastern Himalayas through southern China, the Malay Peninsula and Archipelago, and the Philippines. In parts of China it is called the bamboo-climbing frog, as it frequently hides among bamboo clusters. It is also often found under stones and on trees near houses. While it secretes itself by day, it comes out at twilight for the night's activities. The breeding season lasts from May until the end of August. The foam nest is placed in the shallow water of pools and rice paddies, or the egg foam may be placed on the ground during rainy evenings if there is no suitable pool nearby. The males begin to croak near the breeding site to guide the females to the proper mating place. There are two notes made by the bamboo-climbing frog; one is a low, unpleasant, coughing sound, the second something like a rooster calling to the hens when he has found food for them. There are also two positions of the arms assumed by the male during breeding. At first the female is seized above the armpits and the male lies close to her body with his nose near the back of her head. As the female begins to lay, she flattens her body and extends her legs behind her, which causes the male to move his hands back to her armpits while he ejects his sperm over the eggs. First a small amount of fluid is produced by the female, which she beats into a foam by moving her feet and legs in and out. When some foam has been thus prepared, eggs and foam fluid begin to come out at the same time. With each emission, the female beats the eggs and the foam together with her feet. The beating is not continuous, there sometimes being an interval of several seconds to a minute between beatings. Occasionally the male moves his feet too, as if to help in the process. After all the eggs have been laid, the male, partly buried in the foam, gets away by using his hands to aid in his release. The female detaches herself from the foam in much the same manner. The foam is white when first laid, but its color changes to light brown in a few minutes, and it becomes very sticky. The mass is generally oval and is flattened at the bottom in cases where it is attached to the ground, to a wall, or to vegetation. When it is found on the surface of water, it was washed there by rain, since it is impossible for the female to beat

the mass of foam when in the water. If there is insufficient rain at the breeding season to wash the eggs and tadpoles into standing water, many of the foam nests dry up before the tadpoles can hatch, so that the infant mortality among them is very high. Most of the living eggs are deep in the foam mass, while those on the surface tend to dry up. The incubation period varies with the temperature, being usually six or seven days. When the tadpoles are nearly ready to hatch, the foam liquefies and the embryos become very active in their tiny individual "lakes." Their activity causes them to drop out of the nest into the water below to begin their lives as tadpoles. The amount of food material in the pond influences the size and shape of the tadpoles. In water where food is abundant, the tadpole is fat and clumsy and its abdomen becomes very large. The young frog just after metamorphosis measures about an inch in length, while a fully grown adult is about 2½ inches long.

The Asiatic and East Indian genus *Rhacophorus* includes some eighty species. Most of these suggest *Hyla*, because both have noticeably enlarged disks on fingers and toes for their arboreal existence, and wide heads from which the large eyes project prominently. But the mode of development as well as the anatomical evidence leads us to believe that the Rhacophoridae evolved from the Ranidae, whereas the Hylidae seem to have descended from bufonid stock. *Rhacophorus otitophus* from Borneo (Plate 73) is a good representative of its genus.

## The Narrow-mouthed Toads

(Family Microhylidae)

If narrow-mouthed toads could be given an anthropomorphic description they might surely be called "introverts," each and every one. They love solitude, and usually secrete themselves underground during the daylight hours. Some of them have long, pointed snouts, and all have very narrow mouths, as their common name implies. The pointed nose is ideal in foraging for ants and their larvae. Some of the narrow-mouthed toads take up permanent residence in ants' or termites' nests—they are impervious to the bites of these insects—where they are assured of a fine and nearly continuous meal as they take their toll from the endless lines of workers hurrying along the subterranean corridors. That their retiring way of life is highly successful is attested by the existence of





Eastern narrow-mouthed toad (*Microhyla carolinensis*). Robert S. Simmons

members of the family in the Americas, Asia, Africa, New Guinea, and Madagascar.

In the United States the eastern narrow-mouthed toad, *Microhyla* (called *Gastrophryne* by some authorities) *carolinensis*, may be found from southern Maryland to Florida and west to Texas. Adults are seldom seen hopping about by day, except sometimes in very dark, rainy weather. They are almost entirely nocturnal in habit, and find rich stores of worms, slugs, and small spiders in the grass just outside their burrows. They have definite "home" burrows, from which they travel in radiating paths on their nightly foraging expeditions, returning at the approach of dawn, and, when the weather is very dry, remaining there even during the hours of darkness. Their gait is a series of short but rapid jumps, and it is by no means easy to catch one.

The voice of the male is low and sounds something like the bleating of a sheep. It cannot be heard at a distance of much more than seventy-five feet. When heard closer at hand, the call has been likened to the sound of an electric buzzer. The vocal sac is extended

to about the size of a pea in making each call. The male sits in the doorway of his burrow while performing thus, seemingly oblivious to the approach of a female until he is actually touched by her. Then he ceases his song at once and clasps her in the axillae or across the chest, his palms turned outward. Recognition when another male has been seized is by a slight body vibration instead of by the usual warning note. At amplexus the male's voice changes in quality, but he continues to sing all the time he is clasping his mate. They swim together for a time preceding oviposition; then the male flexes his thighs while the female raises her hind legs and vent to the level of the water, moving her knees in and out. As eggs are being laid, the female's legs extend downward and to the sides, bringing the cloacas of both frogs above water and insuring the fertilization of the eggs by the sperm. Simultaneously the male, being usually smaller than the female, slides forwards so that his vent is slightly anterior to that of the female, bringing his feet under the female's cloaca. Although several hundred eggs are produced in a season, only





Flat-faced frog (*Breviceps mossambicus*). Walter Rose

about thirty are deposited in each cluster. After the last one is laid, the female leaves the water, and this action seems to signal the male to release her.

They breed after the weather becomes quite warm, usually from June to September, long after the tree frogs and wood frogs have finished their calling. The egg mass forms a flat sheet on the water surface, sometimes divided up into little groups of 10 to 90 eggs apiece. The eggs hatch rapidly, the larvae appearing in three days and metamorphosing in another twenty to sixty-seven days, depending on temperature and other conditions. A full-grown adult is  $1\frac{3}{4}$  inches long.

Below the mouth of the newly hatched larva is a pair of dark conelike structures, the adhesive organs, which are used by the tadpole to hold onto objects in the water and thus to prevent itself from being carried about by currents before its swimming ability has developed sufficiently to keep it in its optimum environment.

The Microhylidae include some of the most highly specialized of all Salientia. Their larvae are all very similar in lacking horny teeth in the mouth. The cartilage which supports the upper jaw of most tadpoles is absent in the narrow-mouthed toads; the lower lip is a series of folds, which in some species may protrude well beyond the mouth; the external nostrils do not appear until late in the larval development; the spiracle is usually median, unlike tadpoles of other advanced families of Salientia. The toes of the larvae are always webbed, although this webbing disappears at the time of metamorphosis. The adults swim very well nevertheless, kicking the hind legs simultaneously, with the front limbs folded back along the sides. They are very shy of anything larger than themselves, and become silent on the approach of a human being.

The Mexican narrow-mouthed toad or sheep frog, *Hypopachus cuneus* (Plate 74), gets one of its common names from the resemblance of its call to the bleating of a sheep. It is found from Texas south to Veracruz, Mexico. It likes to hide under fallen palm trunks, in burrows, and in the trash of the pack rat's nest. Its maximum size is  $1\frac{3}{4}$  inches. It looks much like the eastern narrow-mouth except for the yellow streak down its back and the thin light lines along the backs of the legs and arms and down the venter from lower jaw to anus, these lines exactly corresponding to the places where the skin naturally tends to split during molting. The inner edge of the first toe has a sharp spade, making it possible for this little frog to become adept at digging.

In South America we find other members of the family. One of the most widely distributed is *Elachistocleis ovalis*, occurring from southern Brazil to Panama. It has a very pointed nose but looks otherwise very much like its North American relatives of the genus *Microhyla*. *Ctenophryne geayi*, with a pig's nose projecting from a fat little body, lives in the Guianas, Venezuela, and Colombia.

But it is in Asia and Africa that the astounding variability of this family is fully realized. Of the forty-four recognized genera, Asia has thirteen, Africa and Madagascar together have fifteen, New Guinea has nine, and the Americas have seven. While no fossil ancestors of this group have been discovered, it seems possible that the ancestral forms may have originated in the oriental region and Madagascar. Unfortunately the habits and life histories of most of these frogs are still unknown.

In appearance, the South African rain frog, *Breviceps gibbosus* (Plate 76), is a comical caricature of a frog. Its face goes straight up and down in front, while its body is a puffball, being largely inflated with air whenever the frog is away from the safety of its burrow. The large rolling eyes irresistibly suggest some comic stage character. These toads emerge from the ground in enormous numbers after a torrential rain, but, at the first sign of the drying out of the soil, quickly dig in again with the strong, spadelike tubercles on the sides of the feet. This species inhabits the Cape Peninsula of South Africa. *Breviceps adspersus* (Plate 77) also occurs in the southern part of Africa.

African natives believe that the rain frog can bring or withhold much-needed rain from their crops, hence its common name. Because of this supposed power, the natives show it great respect, and if they happen to dig one up when cultivating their fields, they carefully put it back in its burrow and



cover it with soil, adding a little of their own food as an act of propitiation. Because of its habit of living underground most of the time, it is considered to be rather rare. Like most burrowers, it has a spadelike tubercle on the inside of its hind foot, and as it backs into the ground, the dirt is thrown sidewise with outward kicks of the hind feet, while this kicking is accompanied by a slow revolution of the whole body. Its food consists of earthworms and insects, with a preference for termites when they can be had. Its skin is covered with rounded glands that suggest those found in toads of the family Bufonidae, and the skin secretion is irritating to its many would-be enemies. Another device for its protection is a startling shrill squeak, like that of a mouse, which it utters when first captured. The mating call is quite different, however, being a peculiar whistling note which is produced only at this time.

None of the short-headed toads of the genus *Breviceps*, all African, is able to swim, and they never voluntarily enter the water. This bars the possibility of their laying eggs in water, even if there were ponds

in their vicinity. But some species of *Breviceps* live at least fifty miles from the nearest standing water, and their short legs and balloon-like build would prevent them from migrating even a fraction of that distance. In *Breviceps parvus*, a small species from the Transvaal, the exact method of caring for the eggs was discovered, the procedure being as follows: a few large eggs are deposited under a stone or in a burrow by the female, and complete metamorphosis takes place inside the egg capsule. While in the egg the usual tadpole gill slits and tail have already been developed, although these structures are of no use to a land dweller, and they are finally absorbed before the young froglet leaves the egg to wander off and search for its food of small grubs and insects.

*Microhyla* is the only genus found in both hemispheres, for in addition to the dozen species known from the Americas, about fifteen others are known from southeastern Asia. One of the most beautiful of these is *Microhyla berdmorei*, known from Burma south through the Malay Peninsula and Sumatra. It has a marbled pattern of dark brown lines and tan

Asiatic painted frog (*Kaloula pulchra*). D. Dwight Davis





spots on a pinkish ground, the vocal pouch of the male being gray or black.

*Kaloula pulchra* is another strikingly colored frog. Sometimes it is mostly raspberry pink, with a dark brown irregular stripe on the back and other smaller spots on the arms and legs. It is found from southern China throughout most of Malaya, and is often seen hopping about gardens and even entering houses in its continual search for insect food.

Another odd-looking frog is *Glyphoglossus molossus* from Burma and Thailand, which has a peculiar pug-nosed face and distended body, with a very large, sharp shovel on its foot, which it uses for burrowing very quickly out of sight.

Of the remaining genera, practically nothing is on record concerning their habits and life histories. Pet-fanciers in any lands may make valuable contributions to our scientific knowledge by keeping some of these alive and noting carefully all of their activities.

## The Phrynomerids

(Family Phrynomeridae)

There exist today several groups of frogs whose fossil ancestors have never been discovered and whose relationship to other frogs is not clear. One of these is the family Phrynomeridae, known from a single genus, *Phrynomerus*, having some half a dozen species found in Africa south of the Sahara.

The skin secretion of *Phrynomerus bifasciatus* is produced in great quantities if the frog is disturbed; the hands of a human collector have been known to become temporarily inflamed after touching it, and its poison is deadly to other frogs. Its zebra-like stripes of black and brick red may change after a long exposure to light, becoming orange or pink on a

grayish ground color. In very bright light the pink and orange disappear and the entire back becomes gray with a narrow dark vertical stripe. These changes result from a sensitivity to light located in the skin itself instead of in the eyes alone, for if a part of the frog's body is shaded while the remaining part is exposed to full sunlight, the shaded part retains its normal bright coloring.

This frog is hardy and tame in captivity, and it therefore makes an excellent subject for laboratory observation. In nature it hides in the stumps of banana trees, in hollow trees, or in the tunnels of termite nests. It is adept at burrowing into the ground in search of ants and termites, as well as to seek a good hiding place in dry weather. The tips of its toes are expanded and rather adhesive, and it goes up and down the termite tunnels arching its back to get a good grip on the vertical walls. In captivity it accepts flies enthusiastically.

The eggs are laid in masses of 1000 to 1500, and are fastened to submerged weeds or are left lying on the bottom of a pool. The tadpoles look somewhat like those of the platanna, *Xenopus laevis*, but unlike the platanna, they have no tentacles above the corner of the mouth.

The voice of the calling male has been described as a shrill whistle repeated at intervals and audible for three-quarters of a mile. The maximum size of the adult is 1½ inches. Its body is plump, and the rather small head projecting in front gives it a pear-shaped outline. Unlike most frogs, it has a distinct ability to move the neck and can turn its head slightly from side to side. It very seldom hops; instead it walks quickly, its front feet being placed well forward and its body carried above the ground. It has been recorded from Kenya and the Congo south to Cape-town, but it appears to have been given no common name.



# Some Biological Aspects of Amphibians

**I**T was a silent world into which the first amphibians aeons ago emerged from the water—silent, that is, as far as animate sounds were concerned. Of inanimate noises there were plenty—the crash of thunder, the roaring of waves, the howling of winds, and the eruption of volcanoes. But the only air-borne sounds as yet produced by living creatures were the non-vocal noises of insects.

## THE VOICE

The silence was forever broken when the earliest froglike amphibians began to gather in mating aggregations and to make their presence known by some kind of croak or chirp. We do not know exactly when vocal cords were first developed, but they must have been present in some of the ancestral salientians, whose fossil remains have not yet been found, because the possession of vocal cords, and consequently a voice, is practically universal among all living families of frogs and toads.

Caecilians on the other hand are voiceless. Salamanders, also lacking vocal cords, emit at most only a faint squeaking sound that is not in general sufficiently loud to be of use in attracting females to males at mating time. Not all salamanders can make even so much of a vocal effort, since many species seem to be completely voiceless. Among the few known to have a voice is the Pacific giant salamander, *Dicamptodon ensatus*, which has lungs; it is known to produce a low-pitched rattling note or "bark" and, when in danger, a screaming sound. The arboreal salamander, *Aneides lugubris*, and the Monterey salamander, *Ensatina eschscholtzii*, both lungless, produce a mouselike squeak, apparently by expelling air from the closed jaws or through the nasal passages. Newts possess lungs and a larynx; they can emit a sound similar to that produced by rubbing a wet finger over glass.

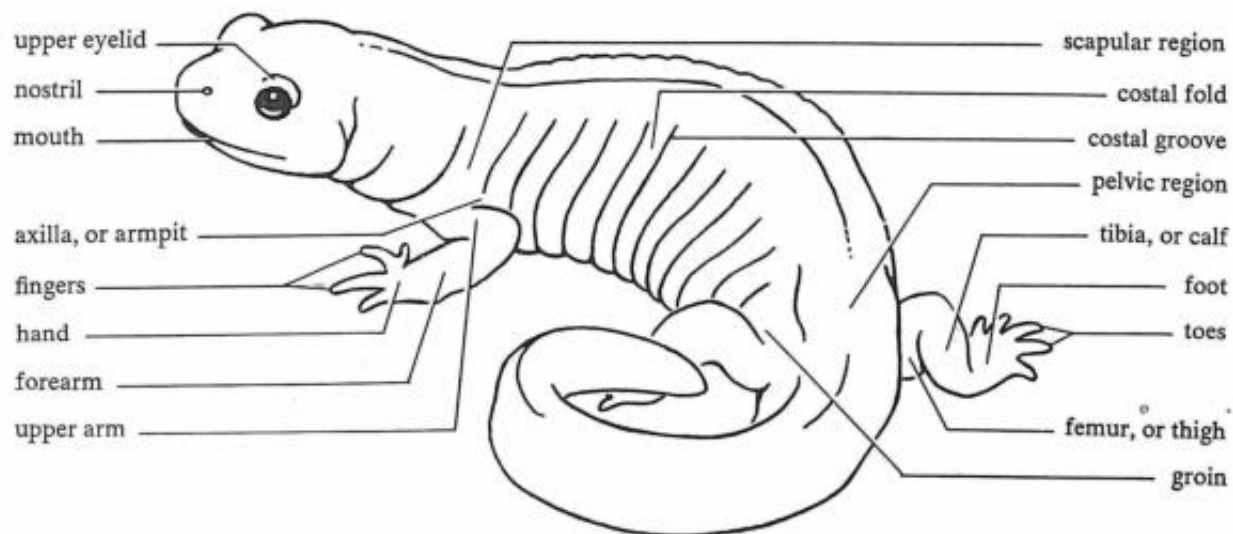
Nearly all kinds of living frogs and toads, however, become quite vociferous, mainly at breeding time, but also to some extent at other seasons of the year when they are not actually in hibernation or aestivation. Most of them have two distinct kinds of calls—the mating call, peculiar to each species in its pitch, periodicity, and duration, which is produced with the mouth closed by a vibration of air over the vocal cords; and the cry of distress or pain, given with the mouth wide open, and of unmistakable significance in its high pitch, urgency, and loudness. This unexpected sound often causes a predator to drop the screaming frog, which, if not too badly injured, instantly leaps to safety. Even when the frog is injured, its cry may act as a warning to others of its species nearby.

The voice of the male of each species of frog is, as I have pointed out, distinctive, and the field naturalist soon learns to recognize the calls of unseen frogs just as readily as he may identify those of well-known birds. Frog calls differ much in quality; those of different species have been described by such adjectives as sonorous, bell-like, bleating, clicking, whispering, and many more besides. Female frogs, when they use their voices at all, give much weaker calls than the males. The female's note may be described as a grunt or chirp differently inflected, and it is not a mating call.

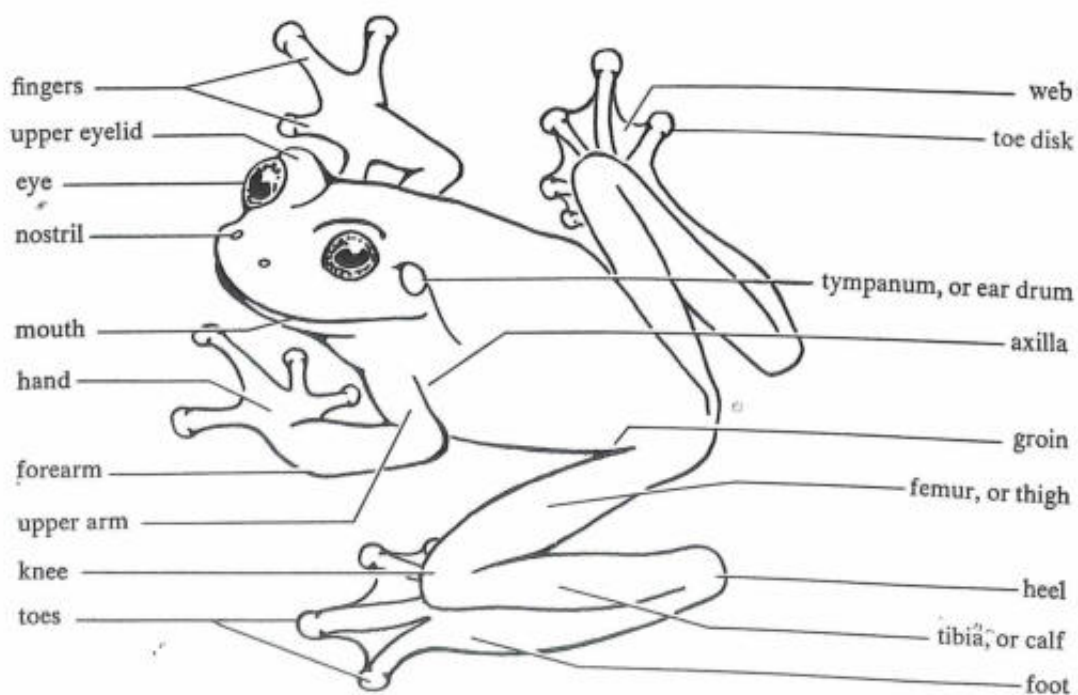
Both sexes produce sounds by means of air that is pumped backward and forward over the vocal cords, which lie on the larynx in the throat between the mouth and the lungs. Since frogs have no separate channel by which air can enter the lungs, they must swallow it. The inner aperture of the nostrils opens into the roof of the mouth, so the swallowing goes on all the time that the frog is on land. The constant movement of the throat is the external sign of this activity. Under water the nostrils are closed, and the



# EXTERNAL VIEW OF A SALAMANDER



# EXTERNAL VIEW OF A FROG





supply of air in the frog's lungs when he went under must last him until he can open his nostrils upon returning to the surface. As the calling is done with the mouth closed, the male can "sing" under water as well as on land.

The sound may be intensified in males of some species by a resonating sac, either external or internal, whose opening appears as a small slit on the floor of the mouth. In making the call, the loose skin of the sac is greatly distended with air momentarily. At the cessation of the sound, the sac empties and the throat becomes normal and nearly smooth once more. Some species have a pair of such sacs, one at each side of the throat, and consequently two slitlike entrances to them, one on each side of the tongue. In those frogs in which the sacs are external, the air with which they are filled during the call causes them to resemble little balloons. When deflated, the outer skin often appears wrinkled, thus giving a clue to their owner's sex. Females lack the vocal pouches and in many species are voiceless during mating, although they can on occasion produce the grunt or the scream of distress.

The vocal sac is formed of an extension of the mouth cavity lining, with sheets of muscle and skin attached to it. If these muscles are thickened, the sac cannot balloon outward when the call is being given, the throat merely expanding a little for the moment of calling; with such a structure the vocal sac is said to be internal. In frogs with thin layers of muscle controlling the sac, the air easily pushes it outward, in which instances the sac is called external. In some toads the single median external sac inflates like a bubble to extend from the chin well onto the abdomen, becoming so large in front that its owner can scarcely see around it. In frogs with lateral external sacs the distension is usually quite as remarkable. In species of *Hyla* different kinds of vocal sacs are found in the same genus, while in some unrelated members of the families Ranidae and Bufonidae the same kind of vocal sac has been independently evolved. The anurans having internal sacs sometimes call under water, but in those with external sacs the call is most often given on land.

The male common European frog, *Rana temporaria*, is known to begin to croak when it is fourteen months old, while the edible frog, *Rana esculenta*, must be eighteen months old before its voice has developed. The arrival of the voice is one of the signs of sexual maturity and hence of ability to reproduce.

In those species that congregate in considerable numbers to mate and lay eggs in water, the male's call is not directed to any particular female. Frogs do not subjectively choose a "favorite" with whom to



Gray treefrog (*Hyla versicolor*). Jack Dermid

Spring peeper (*Hyla crucifer*). Karl H. Maslowski





breed. Instead, the male seizes the first female to come near him.

Since the males usually arrive first at the breeding site, their calls indicate to the approaching female the place she is seeking. A large pond with many frogs in it is thus the source of almost continuous sound for the duration of the mating period—a matter of from two or three days to three weeks.

In the act of mating, called amplexus, the male usually croaks just as often as he did before seizing the female. His position on her back might seem to prevent the extension of his throat during the call, but he elevates his head as far as possible without releasing his hold on the female, thus making room for the proper expansion of his throat. After amplexus with one female is completed, the male is immediately ready to take another female.

The grunting sound sometimes made by frogs is quite different from the mating call, and it serves a different purpose. A male frog may unintentionally seize another male; thereupon the seized one utters the grunt, which is the signal that he is of the wrong sex, and he is then promptly dropped by the first male. Here the grunt is the sign of sex recognition between males. A female that has finished laying all of her eggs may also grunt if seized, in this instance giving the sign to the male that he is no longer required to fertilize eggs.

The duration of the mating call depends upon the species uttering it. On oscillographs, scientists have recorded the voice patterns of many salientians, and have found that no two species give identical records, although allied forms often show somewhat similar song patterns. Sometimes there are overtones inaudible to human ears; these are picked up by the more sensitive oscillograph needle, just as the unsuspected supersonic notes of bats were discovered some years ago by this means. A single call may last only a fraction of a second and be repeated again and again at short intervals for some minutes, or it may occupy several seconds, also with extensive repetitions.

The sporadic croaking of frogs heard at intervals during the summer is usually not a call to breed. It often begins in response to some non-amphibian stimulus, such as the hum of machinery or the whistle of a distant train. Tree frogs often "sing" at the coming of a storm, apparently triggered by the rising humidity. When the gonads have developed in the autumn, however, some frogs frequently begin to call, and there are records of normally spring-laying species that have laid eggs in autumn. When the female does not have the urge to breed, she will some-

times remain at a little distance, appearing to listen to the male as he raises his voice in a vain attempt to procure a mate.

Variations in the volume of sound are related to the amount of air passing over the vocal cords from lungs to mouth and back again. When the throat and sacs are only partially inflated, the call is softer and more trilling in quality than during the active mating season, when they are fully inflated.

A question sometimes asked is how the voiceless frogs cause their mates to breed. In the tailed frog, *Ascaphus truei*, any calling by the male would be inaudible above the rushing mountain stream in which it lives. Furthermore, there can be no specific breeding sites in such rough water. The male therefore creeps about on the bed of the stream among the rocks when he feels an urge to mate. He eventually finds a female, and at once they mate, and the fertilized eggs are attached to the bottom of a submerged stone, where they will not be swept away by the swift current.

The striped mountain toad of South Africa, *Bufo rosei*, has neither a voice nor a tympanum. It has not yet been ascertained how the sexes find each other at breeding time.

The presence of a hearing mechanism in the Amphibia is apparently correlated with the possession of a voice. Salamanders and caecilians have no visible external ears and can hear air-borne sounds only if these are below 244 cycles. In the skull of the larval newt exists an auditory apparatus that suggests the ability to receive vibrations through the lower jaw while the creature is resting on the bottom of a pond. In adult newts vibrations from the ground are transmitted mostly through the forelimbs.

Frogs on the other hand usually have a prominent "ear" located just behind the eye and above the corner of the mouth. It is a thick, shiny membrane, round or oval in shape—in reality the tympanum or vibration-receiving mechanism that corresponds to the eardrum of most reptiles, birds, and mammals. It lies on the surface in the same plane as the side of the head. It is often partially ringed with a circular rim of thickened cartilage that may afford it a slight amount of protection.

Recent experiments in Florida on the homing instinct of the Southern toad, *Bufo terrestris*, prove that hearing is partly accountable for the ability of males to return to the home breeding site after having been taken away at the height of the breeding season and released a mile from the home pond. Drawn by the voices of their companions left in the pond, almost one-fifth of those carried off and released at this



distance successfully found their way home—quite a record for toads measuring less than 4 inches in length and having a hop of scarcely more than their own length.

The extent of the actual home range for each species must be considered in performing such an experiment. The bullfrog, *Rana catesbeiana*, for instance, is a true home body, staying all its life within 100 to 300 feet of its home pond. Toads are more inclined to wander, however. Records of some Fowler's toads, *Bufo fowleri*, that had been marked and released in their home territory after the breeding season proved that at least one individual had voluntarily gone 4200 feet (four-fifths of a mile) from base and returned.

Probably different species have different degrees of hearing sensitivity. The loud croaking of Western spadefoot toads, *Scaphiopus hammondi*, even from ponds containing other equally vociferous species, acts as a signal to all adult female spadefoots within a hearing radius of about six hundred yards to come at once to the shallow rain pond to deposit their eggs. Thus their larvae may have time to complete their rapid metamorphosis before the evaporation of the water can put an end to their lives.

For species breeding regularly in the deeper water of permanent ponds, the urgency is not so great, and consequently one finds the males' voices less loud, while hearing may be less acute over long distances.

Experiments have shown that frogs are insensitive to sounds below 50 cycles a second or over 10,000 a second, compared to the human range of 15 to 15,000. Since many kinds of salientians travel considerable distances to get to their breeding pool—farther than a human can hear the frog chorus, and hence probably farther than the frogs can get an aural signal as to their destination—other factors besides hearing must affect these prenuptial journeys.

The vocal pattern has sometimes been employed to establish relationships among frogs whose kinship had not been otherwise proved. But only when the adults of species to be compared are nearly the same size can this method be used, because the greater body volume of large species endows them with a quite different vocal range from that found in the smaller kinds of frogs. The male of the oak toad, *Bufo quercicus*, a trifle more than 1 inch long, has a dominant frequency of 5200 cycles per second, while *Bufo marinus*, nearly 7 inches long, calls at only 600 cycles per second.

### THE SENSE OF SMELL

The sense of smell in amphibians is localized in cells inside the nostrils and in Jacobson's organ, an

area of specialized cells in the nasal chamber but distinct from the olfactory organs. Jacobson's organ is well developed in frogs and caecilians but is absent in certain aquatic salamanders such as *Necturus* and *Proteus*. It acts as a mechanism for testing the contents of the mouth, allowing the ejection of undesirable matter before it is taken into the stomach. It therefore may be said to assist the olfactory organs in the smelling of objects.

The nostrils are usually in or near the tip of the snout, appearing as two small round or oval apertures, sometimes on a slight swelling but often on the



Fowler's toad (*Bufo fowleri*) calling. Jack Dermid

plane of the head. Even salamanders that have no lungs, and hence do not breathe air through their nasal apertures, possess nostrils for smelling. A good sense of smell is of paramount importance to all burrowing, cavernicolous, and aquatic species: burrowers and cave dwellers move about in total darkness and thus must depend on other senses than sight to locate their food; similarly, some aquatic species feed in waters so turbid with sediment that they cannot see their food animals and hence must smell them out. And the larvae that do live in clear, pure water often feed at night or under stones, where eyesight is of little value in food-finding but smell is important.

Violent reactions occur in some kinds of salamanders at the smell of food in the water surrounding



them. European newts, for instance, dash about wildly if a minced earthworm is dropped into their tank. Even when their food is placed in a bag before being given to them, their keen sense of smell informs them of its presence, and they begin a frantic search for it, often biting at one another before eventually discovering the source of supply. An entire worm is not detected so rapidly, as its body fluids are not being disseminated through the water. Newts with their nostrils stopped up with wax no longer smell anything and consequently fail to find any food. When they leave the water and become terrestrial, they do not completely lose their sense of smell.

All amphibian larvae have a very acute sense of smell. Tadpoles that live in water use their olfactory powers in locating the soft animal food and algae that nourish them, since many are nocturnal or crepuscular feeders. After metamorphosis the adult frog, if diurnal, seems to retain little of its former sense of smell, for in most species this is not developed or only poorly developed. Most burrowing frogs that feed underground, however, need a good sense of smell in locating their prey.

Caecilians, unlike frogs and salamanders, have a short tentacle in a little groove between the eye and the upper lip. It is retractile and quite mobile. Its base is in contact with the nasal passage, especially with Jacobson's organ. The movement of this tentacle toward any odor-producing substance brings very small traces of this substance to the organ, which quickly tests its value or harmfulness as food. The tentacle thus acts as a tactile nose that can detect food independently of the nostrils, its high degree of development in the caecilians being correlated with their burrowing existence and the degeneration of their eyes.

#### THE SENSE OF TASTE

For creatures that feed almost indiscriminately on worms, insects, and other such fare that seems so unappetizing to us, a sense of taste might seem to be more of a handicap than a help. Such is apparently not the case among the Amphibia, however, for in every species taste buds are found embedded in the tongue, jaws, and palate. Although allied physiologically, the organs of taste and smell are quite different in structure. The taste buds are arranged in groups of elongated cells scattered over most of the inner surface of the mouth.

The amphibian's reaction to a taste stimulation is one of snapping and swallowing, whereas that to olfactory excitation is a movement of the head or body. Experiments have shown that different taste buds of

the European newt are sensitive to such different flavors as quinine and salt. This may explain why some tadpoles prefer a meat to a vegetable diet—the wood frog and spadefoot toad tadpoles, for instance, taking scraped meat in preference to algae. And sometimes a noxious, bad-tasting insect is ejected from the mouth of an adult frog unfortunate enough to catch it.

Smell and taste are chemically stimulated senses of Amphibia, but the main receptor of chemical sensations is the sensitive skin of the entire body. Aquatic amphibians thus receive a warning while swimming from a part of a pond with a low degree of acidity into another part where the pH is considerably higher.

#### LATERAL-LINE ORGANS

Other important organs connected with the skin are the lateral-line organs. These are not found in the higher vertebrates but are present in fishes, in all thoroughly aquatic salamanders and their larvae, in some mountain-brook species such as the larger kinds of *Desmognathus*, in aquatic frog larvae, and even in the adults of *Pipa* and *Bombina*. The clusters of sense cells forming the lateral-line organs usually occur in definite rows of little pits on the head and body. In water these cells respond to low-frequency vibrations. They are less specialized than those of fishes, lying completely within the epidermis, sometimes even at the bottom of conspicuous pores. They are pear-shaped, with a shallow depression at the outer end. Sometimes they are in a single row; often the organ subdivides into several short series arranged in a certain way for each species, this arrangement being determined by the lateral-line nerves, which are said to control the mechanisms of equilibrium and posture and to aid in locating food.

When the animal becomes terrestrial these lateral-line organs disappear. In the newt, which goes from water to land and back to water again, they are partly atrophied and covered with skin during the land-dwelling stage, but reappear on the surface as functioning structures after the newt permanently returns to water upon becoming fully adult.

Not every aquatic amphibian has these organs. Those that lack them are presumed to have evolved from land-dwelling ancestors which lost them early in their evolutionary progress. Among the forms that lack them are salientians *Pseudis* and *Calyptocephalus* and the caecilian *Typhlonectes*. Just as significant is the fact that unborn *Salamandra atra* have these organs, although they now live their entire larval life inside their mother's oviduct. The organs thus



seem to be inherited from some ancestral *Salamandra* which had aquatic larvae.

### VISION

The sense of vision is very unequally developed among the Amphibia. Many of the caecilians are blind, because some of their eye muscles and nerves degenerate, and the bones of their skulls frequently grow over the eye sockets. In their subterranean existence sight is unnecessary to them, hence they suffer no inconvenience by being deprived of it.

True eye glands appear for the first time in the amphibians. In most salamanders a single gland extends along the lower eyelid and opens by several ducts onto the conjunctiva. In *Salamandra* this gland is divided into two parts. In frogs only the anterior section of the gland persists. In caecilians a very large gland occupies the entire eye socket and lubricates the tentacle.

The secretion of these eye glands is carried to the nasal chamber by a lachrymal duct opening on the conjunctiva near the inner corner of the lower lid in salamanders, and in the center in frogs. The eyelids, glands, and lachrymal ducts are formed just before or during metamorphosis—a fact that explains their absence in the non-metamorphosing neotenic species such as *Necturus* and *Proteus*.

The blind salamander, *Typhlotriton spelaeus*, lives near the mouth of a cave during its larval life, during which time its eyes function normally. But as it begins its metamorphosis it retreats deeply into the cave to stay in total darkness for the remainder of its life. The eyelids soon draw together and become partly fused. Then the rods and cones of the retina degenerate and the adult loses the use of its eyes completely. But if the larva is kept in the light as metamorphosis proceeds, its eyes develop into functioning organs of sight, while the usual dusky colors of an open-air salamander appear on its skin, instead of the pasty, colorless tints of the habitual cave dweller. Although its ancestors must have been seeking out dark caves for countless generations, the young still develops normally when subjected to outside conditions.

The larvae of the Texas blind salamander, *Typhlomolge rathbuni*, have normal eyesight while they live in surface-flowing streams, but when they are about to metamorphose, they migrate underground and pass the remainder of their lives in subterranean limestone caverns. As they reach the adult stage, their upper and lower eyelids fuse, although the animals apparently receive some impression of brightness when brought out into the daylight.

In burrowing salientians, however, the sense of

sight remains fully developed. Even the eyes of the termite-nest dwellers, the African microhylids, although very small, are sensitive to visual impressions to about the same degree as are those of diurnal and terrestrial frogs.

In most frogs the eyes are set at opposite sides of the head and look out in different directions, so that full binocular vision is not possible at close range. It can be achieved sometimes in about 40 per cent of the field of vision. To the hellbender, *Cryptobranchus alleganiensis*, no binocular vision is possible, since the extreme width of its head prevents the two eyes from focusing on any one object at the same time. This would be a handicap in a salamander depending on visual sharpness in getting its food, but as the hellbender is nocturnal, it depends on its sense of smell, aided by touch, to locate its prey in the water.

Most frogs are rather far-sighted when at rest. Those of the families Ranidae, Hylidae, and Rhacophoridae, and others that like to catch moths, butterflies, and gnats on the wing, must have the longest

Gray tree frog (*Hyla versicolor*). Jack Dermid





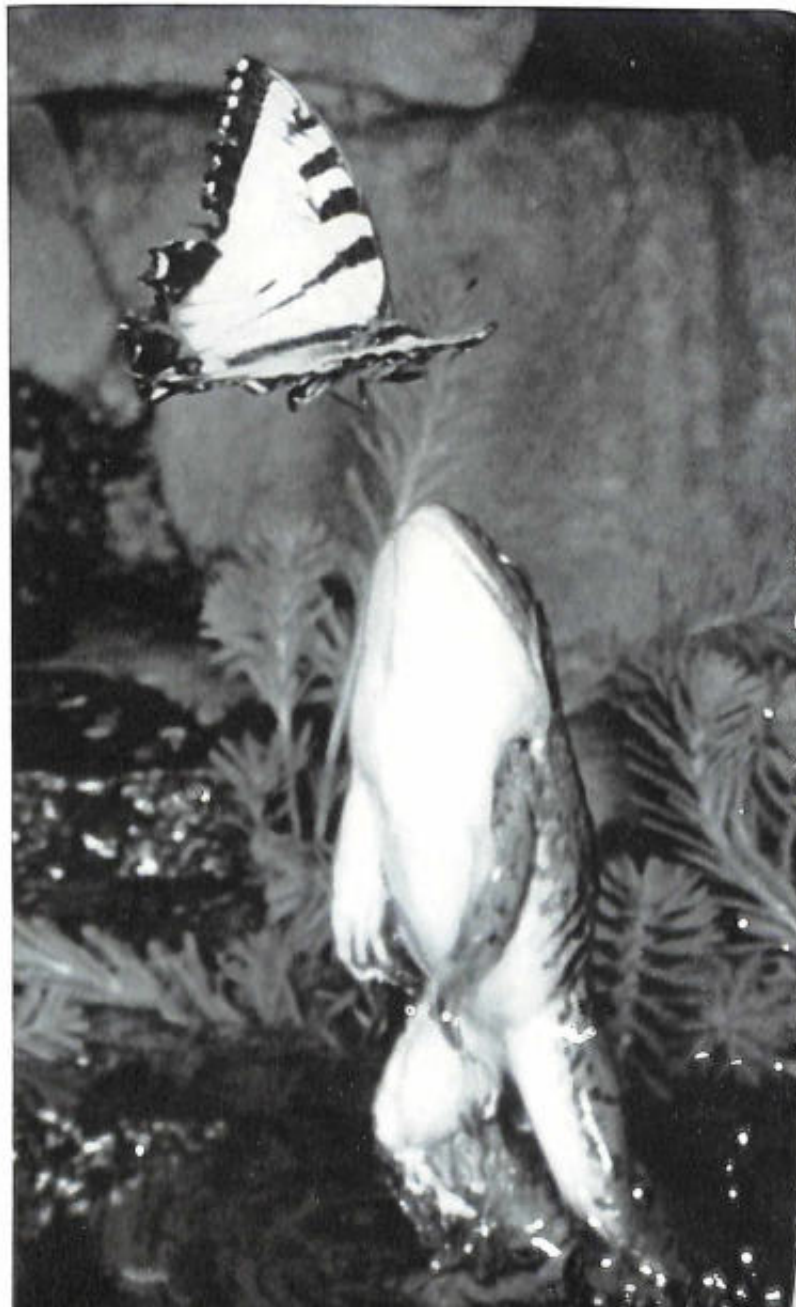
range of vision by necessity, since they must first sight the insect flying toward them and then leap to intercept it at its nearest point of approach—a matter to be judged to the fraction of a second or the frogs will go dinnerless. But even these hunting frogs that leap for their prey seem unable to recognize objects at a range of more than forty or fifty feet. Terrestrial hunters such as the toads pay no attention to a wriggling worm that is much over ten feet away. It is interesting to note that they also have a minimum range of sight, probably due to the lack of binocular vision at close range; thus they do not clearly see a worm at much less than three inches, and will try to back away from it to a distance perhaps equal to twice their own body length—six to eight inches in Fowler's and the American toads—before striking

at it with the tongue. If they do strike at the short range of two or three inches, they often miss, whereas at six inches or so their aim is almost infallible.

All frogs are apparently sensitive to differences between sunlight and shadow. When the moving shadow of an observer walking around a pond touches a frog the animal will jump into deep water at the center of the pond or try in some other way to get farther from the shadow. Although its eyes may have been directed straight toward the intruder, it may show no fear of him until his shadow triggers it to flight.

Many frogs feed at night or on very dark, rainy days. These have the cats'-eye expansion of the pupil noticeably developed. As light decreases, so the area of the pupil increases, and a frog seen by flashlight on

Bull frog (*Rana catesbeiana*) catching swallowtail butterfly. Treat Davidson







Cuban tree frog (*Hyla septentrionalis*), showing eye (at left) exposed and (at right) partly covered by nictitating membrane. (Constance P. Warner)

a dark night shows scarcely any iris because of the pupil's enlargement.

Changes in color in the frogs' skin are not for the aesthetic edification of the frogs themselves, but are indications of skin response to air humidity, temperature, and the nervous condition of the individual frog. The flash colors shown by many species whose skin secretions are poisonous constitute a warning not to bigger amphibians but to creatures of higher intelligence such as wolves and foxes.

The eyes of terrestrial frogs in particular are so placed as to give them a maximum perception of approaching enemies. The eyes project beyond the level of the skull, a most effective manner of seeing in front, to the side, behind, and above at the same time, for on their eyesight depends their very existence—and they are a most attractive tidbit to nearly every other wild creature around them.

The frog has a wide and heavy upper eyelid that is not capable of independent movement, since it is merely a thick skin fold projecting from the top of the head over the upper part of the eyeball. The lower lid sometimes lacks muscles too. In newts of the genus *Triturus*, the edge of the lower lid is controlled by prolongations of the facial muscles, and this edge is thin and partly folded in on itself. A further development of the folding occurs in the Ranidae, Hylidae, and many other frogs, where it has become a translucent or transparent fold of skin called the nictitating membrane. This can be drawn up over the retracted eye by tendons encircling most of the eyeball, and it gives the frog a certain amount of visual contact with the outer world even when it appears to be sleeping with partly closed eyes. This membrane is often marbled with a pattern of colored lines or spots or designs characteristic of the species. In the water, where lurk many kinds of frog-eating fish and aquatic mammals, the nearly transparent nictitating

membrane is drawn up over the eye to protect it while allowing the frog some degree of vision.

Traces of a third eye, once possessed by fossil ancestors of Amphibia, may be found in some of the living species. This third eye, the pineal, was on top of the head, and sensations of light entered the brain through a pineal foramen. The position of the pineal organ is indicated in some tadpoles and a few adult frogs by a translucent, colorless spot on the forehead, but the organ itself is most apparent in the embryo, where it sometimes contains a rudimentary retina.

Since most Amphibia are nocturnal, they have little need of a pineal eye; thus it has changed or lost its function of light reception, acting now perhaps as an endocrine gland in living amphibians. In many species such as the Italian cave salamander, *Hydromantes italicus*, the rudimentary vesicle has become a secretory organ.

The iris of many amphibians, especially of toads and frogs, is beautiful in color, with metallic golden, silvery, or coppery lattices crossing a pastel-tinted ground. Shakespeare was quite correct in referring to the toad as having "a precious jewel in his head." The eye pattern is also characteristic of the species possessing it, as are the striations of the nictitating membrane.

The pupil is black, extending the width of the eyeball, horizontal in most frogs but vertical in some, such as *Pelobates*, *Scaphiopus*, *Phyllomedusa*, and several others. In a few species the pupil is angular or has a serrated outline.

Salamanders as a rule have larger pupils and smaller irides than frogs, with less color in the irides. As salamanders hunt for food mostly at night, a relatively large pupil, which can let in as much light as possible when expanded, is a necessity. The retina, even in some salamanders with degenerate eyes, often remains sensitive to light.





Common European tree frog (*Hyla arborea*). Wilhelm Hoppe

Amphibian eyes are quite variable in size. They are usually much larger in species living in trees or on the ground than in aquatic or burrowing forms.

The eyes have still another use besides that of sight. Since the lower half of the eyeball projects below the roof of the mouth, the act of swallowing is assisted by a downward movement of the eyeball, so that the frog may be said literally to "bat its eyes" while it is disposing of a mouthful of food.

#### THE SENSE OF TOUCH

In nearly all amphibians the tactile sense is well developed. The aquatic species need it especially, and many of these use their long, sensitive fingers to dislodge the small worms, snails, and other living

creatures concealed from them in deep mud or hidden under stones.

Thin-skinned amphibians, such as most plethodontid salamanders and ranid frogs, undoubtedly get much news of their surroundings at first hand through their skins. A mere touch of a windblown blade of grass on the back of a ranid frog is enough to send it on a mad leap to safety from the supposed danger. Thick-skinned toads can stand a dryer habitat than the frogs, which are more subject to desiccation because of the thinness of their integument, and toads must depend more on sight and less on touch for their warnings. They live very well in country where little rain falls during a great part of the year, since they move about mostly at night, avoiding the drying effects of the sun's rays, and retreat by day beneath a stone or under debris where they can find a little moisture. As no terrestrial amphibian drinks by taking water by mouth, it must secure its entire quota by osmosis through its skin from some external source—from dew or rain, or even from wet mud. Some salientians in regions of Australia that are waterless for as long as two or three years at a time have the ability to store water, when it does rain, in special sacs inside the body, and these are gradually drawn upon as desiccation of the surrounding soil proceeds.

In the skin lie numerous free nerve endings between the epidermal cells. Other nerve endings occur among groups of specialized cells, raising the outer skin into little conelike structures called papillae. Sense papillae are found on the feet of frogs and on the backs of breeding female frogs, while similar ones occur on the heads of other frogs and along the lips of lungless salamanders of the genus *Desmognathus*.

The tentacle of the caecilian, already mentioned, is a tactile as well as an olfactory organ, and so too are the tentacles of the larvae of the clawed frog, *Xenopus*; the cirri of some of the plethodontid salamanders may also perform that function.

The sense of touch evidently plays a part in the preference of most amphibians for a confined hiding place where they can spend the hours not devoted to food-getting.<sup>9</sup> They are said to be positively thigmotactic, a term indicating their apparent need for contact with the sides of any cavity they occupy. The dusky salamander, *Desmognathus fuscus*, has been found spending the day in a glass bottle left on the ground in full daylight, its position being usually with its head toward the mouth of the bottle. Even the larva of *Typhlotriton*, which normally shuns light, will lie quietly in a groove in the floor of its tank, even when exposed to bright light. The thigmotactic



instinct in some amphibians thus seems stronger than the aversion to light.

### INTERNAL STIMULI

Not only do external stimuli affect the behavior of amphibians, but internal conditions also activate them in specified ways. If an individual has not fed for some days, the hunger contractions of its stomach become frequent and finally continuous at normal temperatures. Below 13 degrees C. these contractions cease, and when the animal is subjected to heat above 35 degrees C. they are also inhibited, but within these limits the contractions increase in frequency with a rise in temperature. During the breeding season neither frogs nor salamanders take food. It is probable that the increased pituitary hormone changes in the body at that time inhibit the hunger contractions and thus forestall any desire to eat.

Amphibians that live in water must come frequently to the surface to breathe. The exhaustion of the oxygen in their lungs produces an internal reflex that causes them to go where they can replenish their supply of fresh air at the necessary intervals. Sense organs lodged in the muscles and deep tissues of the body keep the animal informed as to its posture. While no sensations that can be measured come from these organs, their effect is to cause automatic or involuntary movements in the animal, all of them presumably to add to its well-being.

There are certain periodic alternations of activity and rest in the daily lives of most amphibians. The European green tree frog, *Hyla arborea*, becomes active between noon and 1:00 P.M., and again from 8:00 to 9:00 P.M. daily, with corresponding intervals of quiet between. It probably does most of its feeding during its active periods, for the hunger contractions in its stomach must have stimulated it to secure food. Temperature and humidity, felt mostly through the skin, likewise appear to cause amphibians to choose different resting places at different times of day.

### THE SKIN

Amphibian skin is a complex glandular integument that performs varied functions. In most forms it is usually soft and moist to the touch, and it contains no visible scales. Exceptions are adult toads and some other terrestrial amphibians, which have thick, leathery skins, seldom moist in the rather dry environment in which many of them live; and the caecilians, which possess small scales buried inside the integument and visible only upon dissection.

During the first stages of the amphibian embryo, only the ectoderm layer of skin is present. It is pro-

vided with cilia that set up currents in the surrounding water and thus bathe the embryo. These cilia thrash in some particular direction—from head to tail in frog tadpoles less than  $\frac{1}{2}$  inch in length, their concerted action moving the tadpole forward slowly even when unassisted by its muscles of swimming, and thus giving it new feeding areas while it is still too undeveloped to seek these for itself.

The skin of amphibians is more complex than that of fish, because multicellular alveolar glands are well developed in the former. There are two kinds of alveolar glands common to the three orders of living Amphibia. The first are the mucous glands, secreting a clear substance that keeps the skin damp in terrestrial amphibians and lubricates it in water if the animal is aquatic. The mucous glands are scattered all over the body, and while they are quite small in size, the amount they can secrete upon stimulation is surprisingly large. Sometimes this secretion is quite viscid; for instance, the slimy salamander, *Plethodon glutinosus*, gets both its popular and scientific names from its abundant flow of sticky mucus. Second are the granular glands—so named because they have a

Common European tree frog (*Hyla arborea*). Ernst Zollinger





granular appearance when stained with plasma dyes—from which flow the acrid secretions that are irritating to the mouths and eyes of other animals that would ordinarily prey upon the amphibians. These glands are often concentrated, as in the parotoids of toads and the warts of some terrestrial salamanders. Their secretions contain alkaloid substances, resembling digitalis, that are more or less poisonous in the stomachs of higher vertebrates, sometimes causing nausea, slackened breathing, and paralysis of the muscles. Not all amphibians with such poisonous skin secretions have the warning red or yellow colors of the arrow-poison frogs. The marine toad, whose skin is one of the most toxic known, is a dull brown or gray.

Other glands that have developed from the mucous glands are those found on the thumbs and chest of certain kinds of male frogs at breeding time, their sticky secretions helping the male to hold the female more firmly while he is fertilizing the eggs. Onto the widened disks of tree frogs' toes, the tubular glands emit a glue-like substance that enables the animals to cling to upright or overhanging surfaces by adhesion.

Another function is performed by differentiated mucous glands that appear on the chin of the male in plethodontid salamanders; the secretion of these glands attracts the female so that she remains quiet while the male's courtship takes place.

Still another purpose is filled by the tubular glands that are especially prominent along the naso-labial groove of plethodontids—that of freeing the nostrils of water and mud by their secretions.

Some salamanders give off characteristic odors that appear to come from their granular or mucous glands. The fire salamander, *Salamandra salamandra*, and the common European toad, *Bufo bufo*, smell like vanilla when handled, and the Sardinian salamander, *Hydromantes genei*, emits a sweet, penetrating smell even if undisturbed. The European frogs *Pelobates* and *Pelodytes* have the odor of onions. The mink frog of Canada and the northern United States, *Rana septentrionalis*, gets its popular name from its characteristic odor. The larvae of frogs and salamanders do not have functional glands until they are nearly ready to metamorphose, and the presence of odors in these young larvae has seldom been noticed, although the mature larva of *Rana heckscheri* has a peculiar sweetish smell. It seems likely that our olfactory sense cannot perceive all the odors emitted by amphibian glands. The hedonic glands of newts and plethodontids secrete substances that seem odorless to us, but the female salamanders find something very attractive about them that holds their attention dur-

ing their courtship by the male. Females have no such special glands in the skin, but a male salamander at the season of courtship may nose a female of another species and reject her immediately, apparently because of her odor, while accepting a female when her skin secretion identifies her as of the correct species.

Amphibian larvae have the epidermis protected by a mantle of cells. At metamorphosis this outer layer flattens and becomes somewhat horny, the change being induced by the thyroid hormone, while the epidermis becomes thicker. In *Siren* and *Cryptobranchus*, aquatic salamanders that retain certain larval characteristics throughout their lives, the skin is thickened and horny in the adult, although most other structures remain those of a typical larva.

Mountain-brook salamander larvae that are in constant danger of being dashed against the rocks or swept downstream by the current have the tips of the digits covered with thick, partially horny caps; in *Onychodactylus* larvae these tips have actually become sharp claws resembling those of lizards. The inner toes of *Xenopus*, the African tongueless frog, have short, horny claws. The ventral suction disk on certain ranids such as *Staurois* is covered with tubercles having horny margins. The rasping teeth of tadpoles that scrape algae from stones for food are likewise horny. Adult frogs and salamanders sometimes produce horny papillae on the back and head, while the rough patches on the male's thumb, arm, chest, and throat are of the same epidermal origin.

A number of flask-shaped cells in the epidermis attach the horny layer to the under layers of skin, but only this outermost layer is shed at molting. The shedding of the old skin occurs several times a year, at intervals of a few days or weeks, and this process lasts from only a few minutes to a day or so. Toads molt very rapidly, while some aquatic salamanders, which must secure friction against some solid object to rub off the patches of loose skin, take longer.

Tests have shown that newts in which the thyroid gland had been removed failed to shed the skin properly, the layers of horny skin remaining on the body even after several moltings. Removal of the pituitary also inhibits the molt, piling up a thick, horny layer in both frogs and salamanders; according to these experiments, the act of molting seems to be caused by hormones from secretions of the thyroid and pituitary glands.

It is unusual to find a shed skin of an amphibian, because toads and many aquatic frogs and salamanders swallow the skin as it comes off the body. The swallowing motions, assisted by the rubbing of the legs, help in ridding the animal of its old cover-



ing. The new skin lying directly beneath the old one often appears much brighter in color.

The skin also serves as a breathing organ—the main one for lungless salamanders. In these, either the skin is very thin or capillaries penetrate it almost to the surface. These same conditions occur in some frog larvae during metamorphosis, when they are making the adjustment from securing their oxygen in water to getting it directly from air.

### INSTINCT

In amphibians, instinct is strongly developed to carry them along their life course without need for much intelligence. The brain is not highly organized in comparison with those of the higher animals that appeared much later in evolutionary history.

Instinct had to come before intelligence, for through instinct alone, living creatures even of the most primitive invertebrate structures were effectively guided through the increasingly complex life functions brought about by evolution, centered on the preservation of the individual and the perpetuation of the race.

Instinctive reactions are thus inborn; hence they are just the opposite of intelligence, which includes the ability to learn by experience. This faculty of learning demands memory, and because amphibians possess only a limited aptitude for memorizing, they fail to retain acquired knowledge very long. Experiments prove that amphibians seldom remember for more than a few weeks anything taught to them in the laboratory, although they can be "re-educated" after their original lessons have been forgotten.

There is, however, quite a variation in the degree of learning ability among the different amphibians. Frogs of the genus *Rana* are usually extremely timid, and their chronic fear may be a hindrance in exercising their learning ability. In the laboratory, they continue to leap off a table, never learning to stop at the table's edge. Toads, on the other hand, soon learn from the first few leaps to hesitate at the edge of the table. In other experiments, toads learned to avoid biting red ants after only one trial. Although they usually refused the ants on the second day, they had forgotten all about their disagreeable experience by the third or fourth day, and again accepted the ants. Some amphibians thus learn as quickly as do some mammals, but retain their knowledge for a much shorter time.

Motor habits, such as traveling through a simple maze, are acquired rather quickly by some amphibians, especially by terrestrial ones, such as newts and toads. It was found that motor reactions neither



Natterjack (*Bufo calamita*). Hans Rosenberg

harmful to the amphibian nor in conflict with activities beneficial to it tended to endure for longer periods. It is now believed that this kind of muscular memory helps toads and some other amphibians to return to the same spot to pass the daylight hours after their night's hunting, and that vision likewise assists to some degree in their homing activities.

During metamorphosis, salamanders forget what they have been "taught" earlier. In adults, the number of errors made in distinguishing between a piece of meat and a piece of wood of the same size increased noticeably during breeding; hence sexual activity also causes a more rapid loss of learned behavior than might occur at other periods of life.

Most amphibians become used to captivity in a few days, and all but the shyest soon cease to batter their noses against the glass walls of their cage in a useless attempt to escape. Some also learn to accept food from their captor's hand, coming toward the nearest side of the cage when they sense the approach of a human being. They can even be taught to emerge from places of concealment upon hearing a sound that has become associated with the proffer of food.

Most toads have a sense of curiosity—which may be considered a first sign of intelligence. A pet Fowler's toad that I had in the days when necklaces of large shiny beads were popular used to walk from one shoulder to the other inspecting the beads, apparently fascinated by the changing highlights in them.

Both the European and the North American newts can be readily "tamed," learning to expect food from the person who tends them. Although in the wild state they normally obtain food at their own horizontal level—that is, in front of them or beside them as



they swim in a pond or walk along its banks—in captivity the aquatic ones form the habit of coming to the surface of the water for food, while the terrestrial ones raise their heads expectantly and look upward when they are about to be fed from the open top of their cage.

The natterjack toad, *Bufo calamita*, terrestrial in habit, can be gradually conditioned to living permanently in water, and, if removed, it resumes its aquatic existence voluntarily even when given its freedom on land. Furthermore, this toad begins to behave in a *Rana*-like manner after its conditioning to the kind of aquatic life common to most ranid frogs. The new environment brings about reflexes in the toad that are not stimulated by a terrestrial existence except at breeding time, when the secretion from the gonads causes their instinctive search for the proper breeding pond. It appears as if the environmental factor of a permanent aquatic existence releases in the toad an instinct to return to water at all times of year if removed from it.

But even the simplest kind of learning derived from experience cannot have been very significant in the evolution of living amphibians. The importance of instinctive reactions is vastly greater, and these reflexes are so exactly suited to preserve life and perpetuate the race that they appear to equal the achievements of intelligence exercised by higher vertebrates for the same ends.

Experiment has shown that a very young salamander embryo just removed from its egg capsule displays no reaction whatever when touched on the skin. At a slightly later stage it turns its head away from the source of stimulation; later still its whole body turns away until it becomes a coil; finally the head turning is reversed before the flexure has passed all the way along the body. When this side-to-side turning is repeated at short intervals, the result is locomotion of a swimming sort. Nerves always grow in an inherent order, causing new responses to occur as new synapses—points of contact between nerve cells—arise between the nerve processes. Thus the young

Common European toad (*Bufo bufo*). Gerhard Budich





salamander swims as a result of the orderly growth of its own nervous system, and not because of a learned experience.

When some salamander larvae were reared for some days in the anesthetic chloretone, while others of the same age were kept as controls in pond water, it was found that the anesthetized ones had developed the same reflexes in the same time as had the normal controls, proving that nerve cells grow at a definite rate and in a definite pattern, and alone determine the behavior at every successive stage of growth.

Sometimes the same kind of reflex accomplishes a different purpose in different circumstances. Although salientians are among the most meek and lowly animals, they usually inflate their lungs with air and bow their heads in a defensive posture when they cannot otherwise escape from danger. The inflated lungs make the body actually larger and smoother, changing the creature's appearance and making it more difficult for an enemy to seize. Variations in the usual defense attitude occur in different kinds of frogs and toads, and sometimes seem to be attempts at offense. *Bufo calamita* when annoyed stretches its hind legs backward, toes on the ground, and with its head lowered and eyes closed rears its body forward in a butting action by means of its strong toe tips. Frogs and spadefoot toads add the scream of fright, while horned frogs, *Ceratophrys*, bite at the enemy. Such offense-defense displays are called forth by vision or sense of touch or both.

The color of the supposed enemy does not appear to evoke this display, but its size and the speed at which it approaches are significant in calling it forth in anurans. Common European toads, *Bufo bufo*, tended to show only the feeding reaction on seeing strange small creatures near them, but showed no reaction at all to objects larger than three square inches unless there were projecting, moving parts. A large ball of wriggling worms caused the toads to drop their heads and perform the butting action, but when single worms began to crawl away from the mass, the defense-fight motions ceased and feeding reactions began. Thus the defense-fight reaction is not primarily against a recognized enemy but against a series of stimuli. This reaction, however, actually may repel the toad's worst enemy, the snake, since snakes are slow in moving when hunting and are often of a size to instigate the defense-fight posture in the toad.

When cornered, toads respond defensively sooner than when they have some way of escaping. True frogs, with their ability to escape danger through speed, do not show the complete defense-fight reac-

tion in the laboratory. Their flight response may have developed phylogenetically at the expense of the alternate reaction. And the snapping or biting reflexes of *Ceratophrys*, cannibalistic by nature, became part of its fight response instead of remaining purely a feeding reaction.

The hunting instinct may emanate from impulses originating in the viscera. The sight of food usually triggers the hunting reaction, which is terminated by the seizing and swallowing of food. The instinct for hunting is better developed in some amphibians than in others. It may also be aided by sound. Toads, for instance, are alerted by an insect's hum for some ten seconds after the sound has ceased, in which interval they frequently find and ingest the prey. Frogs on the other hand have about two seconds of alertness after hearing an insect; hence they are not as successful in hunting for food.

Overstimulation may cause a block in the feeding impulse, or may call up instead the defense or flight reflexes. If food offered to *Necturus* looks different than usual, the impulses to the limbs may be for flight instead of for closer approach. Some salamander larvae while hunting may be put on guard by vibrations felt in their lateral-line organs. Only after the usual smell or sight of their food follows upon the preliminary warning does the snapping reflex occur by which the food is seized. This caution makes for very successful hunting of living prey by these salamanders.

### FEEDING

As adults, practically all amphibians are carnivorous, as they need protein, carbohydrates, salts, fats, vitamins, and water for their metabolism. The insects or other small invertebrates usually chosen as food by the adult amphibian give it a rich protein diet to restore worn-out tissues, the surplus protein being resynthesized into carbohydrates. These are stored as glycogen, and are eventually converted into glucose when needed as a source of energy, as in all animals. During the fasting at hibernation or aestivation, carbohydrates and their derivatives are quickly used up. Thus fat or protein reserves must supply energy to carry the animal through a long fast. Most amphibians are lean by nature, however, and their bodies do not develop the heavy deposits of fatty tissue found in birds and mammals. Nevertheless their much lower metabolic rate allows them to survive such fasts without stores of fat.

Most larval amphibians scrape algae and other water plants for their primarily vegetarian diet. Since this kind of food requires a relatively long alimentary



canal with great absorbing surfaces, the intestines are looped and coiled into a long, doubled, spiral tube in tadpoles. There are a few carnivorous tadpoles, and these have much shorter digestive tracts than do the herbivorous kinds.

Frog tadpoles have been known to live for months without visible food, as they take bacteria and other small particles from the water surrounding them. Some neotenic salamanders, such as *Proteus* and the axolotl, have been kept for over a year without food; under such conditions they use up their body tissues to sustain life, and lose about four-fifths of their weight during this time. Their low metabolic rate allows them to remain fairly active during such a long fast, sustained only by water and their own tissues.

The metabolic rate in amphibians is 18 to 180 times slower than it is in mammals and birds. It appears to be highest during the mating season. Its rate is dependent on the body temperature of the amphibian.

In those amphibians that swim, the body temperature is close to that of the surrounding water, since

water is a good conductor. In dry air the moist skin of amphibians loses heat by evaporation, and when this loss is more rapid than the ability of the animal to maintain its body heat, the frog becomes colder than its surroundings. Conversely, in high humidity, when no moisture is lost from the skin, no heat is lost either, and the frog is warmer than the air. The lungs of thick-skinned amphibians such as newts and toads prevent them from becoming overheated when in a dry environment, but few other amphibians that have thin skins that desiccate quickly can remain long in completely dry conditions.

Amphibians usually cannot endure high water temperatures either. *Ascaphus* must have the excessive coldness of mountain torrents—never more than 40 degrees F. An optimum of around 65 degrees F. suits many aquatic species, although some frog tadpoles were found in hot springs registering over 100 degrees F. *Typhlotriton*, on the other hand, has small tolerance for any water temperature above that of underground streams; hence it is restricted to cave life.

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## How to Keep Amphibians as Pets

**A**MONG the nearly three thousand kinds of living frogs, salamanders, and caecilians, perhaps only one-tenth have been kept in captivity long enough to give us an adequate idea of their habits and life histories. The extensive animal collections of ancient Egyptian pharaohs and Indian rajahs have been made known to the modern world by stone carvings on temple walls and by copies of written records. While it is doubtful if these early collections contained anything so small as an amphibian, they were the beginning of serious attempts to imitate the different environments under which wild creatures exist. Europe and North America in the eighteenth and nineteenth centuries had ardent students of the Amphibia—men who often became great scientists. The twentieth century has seen the installation of public and private zoos, which include even the more secretive and less spectacular amphibians, in almost every country in the world. In many regions there are trained specialists,

who have spent long years in the close investigation of life cycles, physiological processes, biochemistry, and many other phases of the existence of their local amphibians. And still much remains to be learned about even the common forms.

In all regional studies, the work of the taxonomist comes first, for unless the scientific names of the creatures to be studied are accurately determined, the results of the study will be without value. Therefore the first act of the collector should be to have his animals named by a specialist, either by sending photographs of them, including the exact locality in which each animal was collected, or by preserving one or two individuals and transmitting them along with the required data. The name and address of the specialist in almost any group of amphibians can usually be secured from the curator of the nearest museum.

When the name of the amphibian to be kept as a pet has been learned, it is usually possible to find out



something about its food and shelter requirements from published notes about this species or some closely related one. It is best to choose pets of medium size as a first venture, as small ones escape or may be overlooked at feeding time, while large ones confront one with the problem in winter of getting enough food to satisfy them. They should also be rather unspecialized in their food requirements, since the task of obtaining one favorite kind of insect at all times of the year, for example, is not a simple one.

Aquatic frogs, tadpoles that have begun their metamorphosis, and some salamanders do well in an aquarium planted thickly with water plants. Bits of meat and small worms are the accepted diet for the frogs and salamanders, but at feeding time it is better to dip them out and feed them in a separate shallow pan of water, since with this system no uneaten food remains in the aquarium to pollute it. Tadpoles in the early stages are natural scavengers, and may be fed in their own tank, for they may be depended on to clean up the fragments of the meal if there is not too much of it. Pond snails keep the glass clean of growing algae, and the surplus snails also serve the salamanders as a tasty treat sometimes. There are also scavenger catfish that may be obtained at aquarium shops to help in the task of keeping the aquarium free of debris.

Tadpoles should also have abundant supplies of algae, easily obtainable from any stagnant pond, since they find much of their food there during the time before their mouths have become adapted for terrestrial existence. They also like to scrape a meat bone for its animal matter. A flat rock projecting just above the water level will provide a resting place for the metamorphosing tadpoles, since they may drown

if left wholly in water at a time when their air-breathing lungs are just beginning to take over. At this time it is also necessary to screen the tank, for the little froglets may jump out in their haste to leave the water.

Terrestrial frogs and salamanders may be kept in a vivarium or cage partly filled with damp soil into which a shallow container for water is sunk. The ideal vivarium should have a zinc-lined bottom or be otherwise waterproofed. A six-inch layer of moist earth or leaf mold from the woodland or garden should be placed on the floor of the cage, not forgetting the small pan of water. Little caves of flat stones or chips of wood, or even a flower pot turned on its side, should be provided, for most amphibians love privacy and like to spend the long hours of daylight in some sheltered hideaway. The side of the vivarium may be of glass for a better view of the inmates, or of smooth wood with a window of screen wire. The top should be a very tight-fitting lid, preferably hinged and with a staple for secure closing. It is astounding how small an aperture a frog can wriggle through, so in order to keep your pets safely where they belong, there must be no crevices wider than a quarter of an inch anywhere in a cage destined for average-sized inhabitants. Newly captured frogs have a bad habit of leaping up against the top of the cage in their first frantic efforts to escape, thus bruising their noses and often injuring themselves. This may be largely prevented by giving them a deep layer of damp moss into which they can burrow. After their fear has diminished, some of the moss can be removed, and you can then see your pets in their cage.

When in doubt as to the precise needs of an animal, construct its cage so that part of it is a shallow

Bronze frog (*Rana clamitans*). Robert S. Simmons





swimming area and the rest is damp soil planted with ferns or other moisture-conserving plants, with the necessary flat stones to provide comfortable hiding places. The new animal will soon find the sort of surroundings it prefers when such a choice is offered.

Animals from very cold mountain streams seldom live long unless their cage is cooled to the accustomed temperature. An old refrigerator can be pressed into service here, although you will not have the pleasure of seeing your pets on display. A cooling unit such as most zoos have for special cold cages may be installed by an electrician.

Burrowing amphibians may be kept in a glass jar with small perforations in the bottom for drainage. The jar should be nearly filled with sandy soil and dead leaves, the animals placed inside it, the top covered, and the sides wrapped in black paper. After a few hours the black paper can be removed for a short time, so that you may see what your pet is doing underground, since some of its newly made burrow will be in contact with the sides of the jar. The paper must be replaced, so that the animal may remain in undisturbed seclusion.

A food supply for captives must be assured. Many frogs and toads, and most terrestrial salamanders, relish earthworms and small soft-bodied insect larvae. These can be collected in the garden or wood lot and placed in the moist earth on the floor of the cage, where they will emerge eventually to fulfill their role as frog food. Some frogs eat only insects on the wing, and the providing of such food poses somewhat more of a problem. The despised housefly can be lured into an outdoor wire trap baited with carrion, then released into the frogs' cage. For very small frogs, fruit flies can be easily cultivated on stale pieces of fruit in a wide-mouthed bottle left open on the window sill. Larger frogs relish grasshoppers. A homemade insect net can readily be constructed from a circle of heavy wire attached to a short handle, with a long, sleeve-like net of cheesecloth slipped over the wire circle. Many a good frog meal may be secured by scooping this net along the grass or through low branches.

Care should be taken to bring together only frogs that are nearly the same in size. As I have already explained, frogs take only moving food, and they do not have sufficient awareness to distinguish between an insect and a small frog.

The size of your vivarium will depend upon the number of inhabitants you may choose to keep there. Frogs will die through overcrowding, just as most other creatures do. A cage measuring approximately twelve by twenty inches, with a height of twelve inches, will comfortably house five or six frogs of moderate size, such as the bronze frog, *Rana clamitans*. If a more "nervous" species is kept, such as the leopard frog or the pickerel frog, *Rana pipiens* or *Rana palustris*, the cage should be higher, to prevent them from battering their noses against the top in their wild leaps for freedom.

A caution about keeping *Rana palustris*: the skins of these frogs give off a poisonous secretion that is harmless to human beings but fatal to other kinds of frogs confined in the same cage. As I have mentioned, nearly all frogs secrete more or less acrid substances from their skins. This is one of their protective devices, as the poison sometimes stings the mouth of the predator which has seized them and causes him to drop them instead of swallowing them.

When frogs are kept in a small tank, even one with running water, a disease called "red leg" may sometimes develop. This is fatal if left untreated. If the affected frogs are immediately put into a .15 per cent solution of common salt and water, the disease can often be cured.

Having secured and installed your pets, your main pleasure and profit is to come. Keep a notebook by the vivarium, and jot down the hours at which the animals begin and cease their activities, when and how much they eat, their preferred hiding places, whether they climb or burrow, how often they call (if you are keeping any at breeding time), and other facts of their daily existence. You will be fortunate indeed if they mate and produce young in your vivarium. For a rare species, a photographer with a fine lens should be induced to make a pictorial record of the actions of the pair and of their eggs or young at different developmental stages. In some tropical countries scarcely any of the amphibian life histories are known in detail, and any observations on their habits may be reported to the nearest museum or to a specialist who is engaged in studying them. Unexpected facts about these rare and little-known creatures may come to light some day—and it may be in your vivarium.



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